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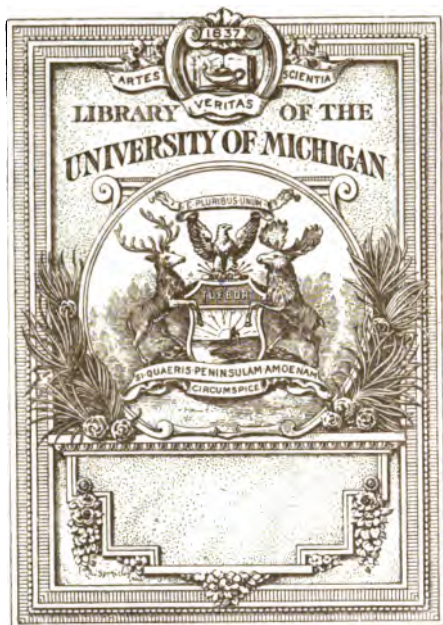
# INVESTIGATIONS FOR THE PROMOTION OF THE OYSTER INDUSTRY OF NORTH CAROLINA.

BY

CASWELL GRAVE, Ph. D.,  
*Director of Fisheries Laboratory, Beaufort, N. C.*

Extracted from U. S. Fish Commission Report for 1903. Pages 247 to 341, 11 plates.

WASHINGTON:  
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OYSTER CANNERY AT BEAUFORT.



UNLOADING OYSTERS AT A CANNERY, SHOWING TUBS.

# INVESTIGATIONS FOR THE PROMOTION OF THE OYSTER INDUSTRY OF NORTH CAROLINA.

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## INTRODUCTION.

The following report is based upon a study of the physical and biological conditions of natural and planted oyster beds in various localities in North Carolina, and contains a record of experiments in oyster culture conducted in Newport and North rivers near Beaufort. The physical and biological investigations, which were conducted from the U. S. Fish Commission steamer *Fish Hawk*, were begun in October, 1899, and, after an interruption extending from the end of March to the first of November, were completed in December, 1900. The experimental work covered a period of three years, beginning in April, 1900.

The objects of the work of the *Fish Hawk* were: (1) To ascertain the present extent and condition of the natural oyster beds in certain sections, for the purpose of comparison with determinations by Winslow on the same ground in 1886-1888; (2) to study comparatively the biological conditions of a number of good natural oyster beds and typical planted areas, with the object of determining the natural cause, if such exists, for the failure of the planted beds; (3) to study the physical and biological characters of the bottom and water of various localities for comparison with the conditions prevailing on good oyster-producing localities of the North, and (4) to collect statistics bearing upon the value and extent of the oyster fishery of the State in the past and at the present time.

Boatswain James A. Smith, U. S. Navy, commanding the *Fish Hawk*, assisted by Mr. W. F. Hill, of the U. S. Fish Commission, conducted the hydrographic survey of the sections investigated and made accurate charts of each, showing the natural and planted oyster beds, the character of the bottom, the depth of the water, the direction and velocity of the currents, and such other conditions as may, directly or indirectly, affect the growth of oysters.

Data showing the extent of the oyster industry in all its branches were collected by Mr. C. H. Stevenson.

In the investigation of the biological and physical conditions of the oysters and oyster beds, the following factors were considered: (1) The organisms that make up the food of the North Carolina oysters; (2) the source of this supply and its richness in different localities and at different seasons of the year; (3) the effect of bottoms of different character upon the growth of oysters; (4) the effect of water of different densities upon the growth and condition of oysters; (5) the enemies and diseases of North Carolina oysters; (6) the animals and plants that are found living with the oysters on natural and planted beds.

The experiments were designed (1) to determine whether it is possible to develop a profitable industry in oyster culture in North Carolina on the grounds available for planting purposes, and (2) in case no insurmountable obstacles to the growth of marketable oysters on these grounds should be found to exist, to develop simple methods of oyster culture by which the failures hitherto attending attempts to grow oysters on planted beds might be avoided in future operations.

Owing to additional duties, it became necessary at the beginning of the second season for me to have an assistant in the experimental work, and Mr. O. C. Glaser was employed. The experiments were at first conducted jointly, but during the third season Mr. Glaser was alone in that phase of the investigations, following the original plans, however, and using the methods already adopted. He also began some further experiments on the growth of oysters, a description of which is included in this report (pages 329-341).

The survey of the oyster grounds and the experiments in oyster planting have been carried on jointly by the United States Fish Commission and the North Carolina Geological Survey, the greater part of the expense connected with the former being paid by the Fish Commission, the Geological Survey paying the greater part of the cost of the experiments. To Prof. J. A. Holmes, State geologist of North Carolina, is due much of the credit for any advantage to the oyster industry of North Carolina that may result from this investigation. It was at his suggestion that the United States Fish Commission began the work, and his plans have been followed by those in charge of the various lines of investigation. Prof. W. K. Brooks and Prof. H. V. Wilson were also consulted in regard to the biological work, and it is a pleasure to acknowledge the helpfulness of their advice and encouragement. Mr. Hollister Potter, of Beaufort, generously placed at our disposal the oyster shells needed for the planting experiments, and I take this opportunity to thank him publicly for the many evidences of the sympathetic and intelligent interest he has taken in the work from its beginning. Thanks are also due to Capt. J. A. Smith, the other

officers, and the crew of the *Fish Hawk*, from whom I received many favors while stationed on the vessel.

In the preparation of this report free use has been made of the investigations of Captain Smith and Mr. Stevenson; and the chapters on the anatomy and development of the oyster, at the request of Professor Holmes in the special interest of the North Carolina oystermen, have been reprinted from the United States Fish Commission Report for 1897.

#### METHODS.

The exact conditions which are most favorable to the growth of oysters and which determine their quality are not sufficiently well known to make it possible, at present, to predict the results of oyster planting in an untried locality. It is altogether possible, too, that sufficient data may never be compiled from which such predictions can be made, but the use of accurate methods of observing and recording certain of the conditions under which the oysters of different localities live is a step in this direction which should be continued. The published observations on the density of the water on oyster beds in almost every oyster-producing region along the Atlantic coast are such as to be of great value to prospective oyster planters. Other factors, such as the general character of the bottom, depth of water, and velocity of currents, have also in a few instances been well described, but the terms used are usually indefinite, and nothing is given concerning the methods employed. In order to have real value in comparing the different localities, all observations on the same condition or set of conditions should be made according to uniform and accurate methods. In the work of the present survey, therefore, considerable attention was paid to this subject, and whenever possible methods already in general use were adopted.

The description, which follows, of the methods used in the work of the biologist does not include methods of oyster planting, as they are best considered in the chapter dealing with the experiments.

The salinity or specific gravity of the water over the oyster beds was determined in the usual way, Hilgard's ocean salinometer being used. This apparatus consists of a copper cup for holding the sample of water, and a series of three sealed glass floats, each float a cylindrical bulb with a slender stem, the bottom weighted with a small amount of shot and the stem containing a graduated scale, which in the first float reads downward from 1.000 to 1.011, in the second from 1.010 to 1.021, and in the third from 1.020 to 1.031. The weight in the first is just sufficient to cause the float to sink in fresh water to the top of the scale, marked 1.000, the specific gravity of fresh water; as salts are dissolved in the water the specific gravity is increased, in pure sea water reaching 1.023-1.027. Float No. 1 is therefore used for determining the specific gravity of brackish water, No. 3 in ascertain-

ing the specific gravity of ordinary sea water, and No. 2 for water between these grades.

The specific gravity varies to some extent with the temperature, being less when the water is warm than when cold. Thus in work requiring very great accuracy it is necessary to standardize all specific gravity observations—that is, to calculate the error in each case due to temperature with reference to an adopted standard. For all practical purposes, however, this inaccuracy is not great enough to materially modify results, and may be disregarded.

The water over the oyster beds was examined frequently at different stages of the tide and at different seasons of the year. Readings from the salinometers were regularly taken and recorded, and at the end of each month a general average was made. These averages appear in this report in the food tables.

The apparatus for determining the velocity and direction of the currents which flow over the oyster beds was designed by Prof. J. A. Holmes and consists of a cylindrical “drag” suspended by a wire from a small floating buoy. The distance between the buoy and the drag is regulated according to the depth of the water, the aim being to have the drag suspended in the swiftest part of the current. To the buoy or float is attached a long line, wound upon a reel, on which are tied at intervals of 50 feet small pieces of colored cloth. In determining the velocity of the current in a certain locality by means of this apparatus, a launch or other boat was first anchored in the channel and the drag and float lowered from the stern. As soon as the drag filled with water and sank, the line was allowed to pay out until the first mark appeared; it was then held until the timekeeper gave the signal to set it free. The time required for each of the marks on the line to be carried past a mark on the stern of the boat was noted, and from these observed intervals the rate of the current per mile was calculated. Numerous observations and calculations of this kind were made in each locality, and an average was computed. These are shown on the charts and in the text.

The character of the bottom in each locality was carefully examined, first by means of a sounding rod, and then from a sample collected by using a short piece of sharpened iron piping welded to a long iron rod. This being thrust into the bottom, unless the latter were composed of pure sand or shells, the instrument came up filled. The contents were examined in the laboratory under the microscope when desirable.

The constituents of the food of oysters have been repeatedly determined, but the cases are few in which attempts have been made to ascertain the amount of each constituent and its source. The interesting qualitative examinations made by Lotsy<sup>a</sup> gave a general idea of

<sup>a</sup>J. P. Lotsy.—The Food of the Oyster, Clam, and Ribbed Mussel. U. S. F. C. Report 1893, pp. 375-386.

the food of Chesapeake oysters, but they do not show the food value of the water. In his report on the oyster beds of Louisiana, Moore<sup>a</sup> gives the actual amount of food found in a given quantity of the water taken over the best oyster beds, the calculations based on examinations with the microscope and the Rafter cell. A very similar method was employed in my work, but before describing it the method used by Bashford Dean<sup>b</sup> in dealing with the same problem in the oyster survey of South Carolina waters may appropriately be discussed. Dean used a chemical test in determining the food value of the water, the amount of albuminoid ammonia being taken as representing the amount of available oyster food, or at least supplying data from which the relative value of different localities for oyster culture might be compared. In obtaining a specimen of water for analysis he proceeded as follows: Two liters of water was collected 1 foot from the bottom over the oyster grounds, brought to the laboratory, and after being vigorously agitated was allowed to stand for a few minutes so that the sediment might settle. A sufficient quantity of water for analysis was then taken from the middle of the jar. It is here supposed, as is shown by the following quotation, that the organisms which constitute the food of the oysters will remain suspended, while the organic impurities will have settled: "The specimen represents the average prevalence of oyster food in the given locality, and, if properly collected, it may be proven by the microscope to be practically free from the organic matters which should not be included in the food of the oyster."

After my study of the North Carolina oyster, I can hardly agree that the above method is in any way reliable in the data it supplies, and, since it may prove to be of economic importance to be able to determine, previous to an expensive oyster-planting operation, the food resources of a locality, I have endeavored to perfect a method which will be fairly accurate in its results. My reasons for discarding Dean's chemical test for a microscopical examination of the water are: (1) No matter how carefully the specimen of water has been collected it is sure to contain an abundance of organic impurities, which do not quickly settle but remain in suspension for a considerable time—several hours. (2) Among the first things to settle to the bottom, when the water is freed from currents, are some of the largest and most valuable food forms of the oyster—for example, *Eupodiscus*, *Coscinodiscus*, and *Melosira* (see figures, page 285); while among the last to settle are the light spiny diatoms of which the oyster can make no use and of which the water is so full—for example, *Nitzschia* and *Rhizosilenia*. The former would not be included in the chemical test,

<sup>a</sup> H. F. Moore: Report on the Oyster Beds of (14) Louisiana. U. S. F. C. Report, 1898, pp. 45-100.

<sup>b</sup> Bashford Dean: "The Physical and Biological Characteristics of the Natural Oyster Grounds of South Carolina." Bull. U. S. F. C., 1890, pp. 335-361.



whereas the latter would. (3) Copepods and other small crustacea, and various larval forms which are so very common at times in all salt and brackish waters, form no appreciable part of the oyster's diet, yet these would be included in a chemical analysis. (4) While an oyster depends wholly upon what the currents bring within reach of its cilia, it does not passively accept all that is brought. I have abundant reason for believing that the oyster possesses a limited amount of selective power in feeding and is able in a measure to discard objectionable forms. Very active creatures, like small crustacea and larvæ, are seldom caught, being able to free themselves from the incurrent streams of water set up by the ciliary movements of the oyster.

From the above facts it can be readily seen that before any determination of the food value of the water of a certain locality can be made it must be known what forms existing there constitute the oyster's diet, and the conclusions must be based upon the abundance of these forms and not upon the abundance of organic forms in general. The method followed in these investigations, which proves to be fairly accurate, was carried out as follows: A liter of water was carefully collected 1 foot from the bottom in the locality under consideration. This was done by lashing a bottle of 1 liter capacity 1 foot from the end of a pole. When the pole was thrust to the bottom the cork was drawn by a string attached to it, and when the bottle had filled it was brought to the surface and unlashed, recorked, and labeled. A number of oysters were then tonged from the same locality<sup>a</sup> and three were chosen which had a length of not less than 3 and not more than 4 inches. The contents of their stomachs were removed by means of a medicine dropper thrust into the stomach after one shell had been removed, a very simple process when the position of the stomach is known. The stomach contents were examined as soon after removal as practicable. The amount taken from three oysters was found to be seldom more than 10 cc. When less, water was added; when more, it was allowed to settle and the clear surface liquid was removed, the examination thus beginning each time with 10 cc. of the food solution. This liquid was violently shaken in a bottle and 1 cc. quickly removed and put into a Rafter cell,<sup>b</sup> where it was carefully examined and the number of food forms estimated, the process being repeated twice. From the three estimates thus obtained the amount of oyster food in the entire 10 cc. was calculated, and this divided by 3 gave the amount per oyster.

The specimen of water was allowed to stand for eighteen to twenty-four hours, until all the sediment and organisms (except small crustacea and swimming larvæ) had settled and formed a definite layer on

<sup>a</sup>If it be desired to determine the food resources of a locality in which no oysters are found it is only necessary to plant a few oysters a few days before the examination is made.

<sup>b</sup>The Rafter cell and the method of using it are described on pages 366-367 of J. I. Peck's report on "The Sources of Marine Food," U. S. F. C. Bull. for 1895.

the bottom of the bottle. In localities where *Peridineæ* were found to constitute a perceptible part of the diet of the oysters, formalin (20 cc. per liter) was added to the water, it having been found that otherwise these plants were all lost in removing the water, which was carefully siphoned off to as low a level as possible without disturbing the settlings. The water and settlings remaining in the bottle after two rinsings were put into a smaller bottle (6-ounce wide-mouth) and again allowed to settle. After a second siphoning away of the clear water the settlings had a volume not exceeding 15 cc., and the diatoms and other organisms in this residue which belong to the species that have been found to make up the diet of the oysters, were counted in the same way as those in the stomach contents.

There are usually to be found in an oyster's stomach, or in the settlings from a specimen of water, several species of organisms, chiefly diatoms, and most of them minute forms. I have found by calculation that the food contents of a given liquid may be very accurately expressed by considering the number of the large forms only; for example, it was found that one *Eupodiscus radiatus* is equal in volume to more than one hundred and fifty individuals of the small species of *Coscinodiscus*, and although the latter is quite numerous in oysters from Newport and North rivers, it may be discarded without affecting the result.

Observations as to the food resources in Newport and North rivers were made and recorded weekly during the summer seasons of 1900, 1901, and 1902. From these records have been made the monthly averages which appear in the food tables on page 289. The examinations made in Pamlico Sound covered but short periods of time, in 1900, so that in each case one average only has been made.

The methods used by Moore in his work in Louisiana differ from those just described only in that all species of diatoms found in the water were counted and given as the food value of Louisiana waters. When, therefore, in his report on the oyster beds of Louisiana (p. 54), Moore states that the food value of the water over the beds in False Mouth Bay is 22,000 diatoms per liter, it does not follow that the supply of available oyster food in that locality is greater than that in the Beaufort region, where I have found each liter to contain about 14,654<sup>a</sup>, for if all species of diatoms had been counted in the latter place the number would have been fully equal to and usually greater than that given by Moore.

The method devised for determining the time required by an oyster to get a certain amount of food from the water is described on page 291.

For ascertaining the condition of individual oyster beds the methods were suggested by, and carried out under the direction of, Capt. J. A. Smith, of the *Fish Hawk*. The oystermen were questioned as to the

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<sup>a</sup>The average from results of the work of three seasons in Newport and North rivers.

usual catch they had been able to make on the beds, and this information was supplemented by the results we were able to get by tonging and dredging the beds.

In our tonging operations a certain definite area was covered, and an accurate count made of everything brought up by the tongs, including marketable oysters, small oysters, spat, shells, and other animals.

For the examinations by dredging, a regular oyster dredge boat was hired, and towed over the oyster beds in various courses by a steam launch. When the dredge on one side of the schooner had been on the bottom one minute it was hauled in and emptied, the one on the other side being let down. This was continued until the schooner had crossed the bed, when another line of dredgings was begun. The contents of each dredge haul were examined and counted. The exact position of the schooner at each haul was determined by sextant angles, signals having been erected on shore for this purpose before the work began. On certain beds in Pamlico Sound, which were exposed to the action of waves, oyster shells with their hinges intact were abundant. These were thought to indicate the amount of damage done to the beds by the recent storms. It was evident that the oysters had recently died, whatever may have been the cause.

#### SURVEY OF NEWPORT AND NORTH RIVERS.

##### GENERAL CONDITIONS.

The survey of Newport and North rivers was conducted from the steamer *Fish Hawk*, the men being transported to and from the oyster beds in launches and row boats. The work covered the period from October 6 to November 23, 1899, in Newport River; from the latter date to January 7, 1900, in North River.

Before beginning the work in either case, signals were erected by Captain Smith at various places along the shores, to be used in making triangulations of the oyster-producing regions. From these angles and the sketches and observations thus made, charts were constructed by Mr. W. F. Hill, giving the location and extent of each of the natural and planted oyster beds, the depth of the water covering them, and the character of the bottom. The positions of the stations at which observations were regularly made on the density of the water and the velocity of the currents are also shown, and in connection therewith the averages for the entire survey of the observations made at each. A record of the density observations at certain of these stations during the three seasons immediately following the survey are given in the food tables on page 289.

The total areas of the natural oyster beds in Newport and North rivers and tributaries, including "reefs" and areas of scattered

oysters, were found to be 257.7 and 135.22 acres, respectively. Comparing these figures with those given by Winslow for 1887, it is evident that during the twelve years that intervened the beds have become considerably reduced in size. Winslow gives 403 acres as the area of the Newport beds, not including those of Carrot Island, and 242.75 acres as the area of the beds of North River. His estimate that the entire area in each river not now occupied by natural beds was available and suitable for oyster culture in some of its branches is also very much greater than the estimate of Captain Smith, who, guided by the experience of those who have planted oysters in these waters since the survey by Winslow, gave 3,840 acres as the amount of ground suited to planting in Newport and 3,600 acres in North River. My own experience, acquired since the survey in 1899, would lead me to reduce the amount still more, limiting all planting to such unoccupied bottoms as are found above the lines referred to in the discussion of the natural beds on the next page.

The amount of ground under cultivation in Newport River at the time of Winslow's survey was 28 acres. In 1899, although as many as 170 entries of ground had been made since 1887, there were no beds on which the taxes for the previous year had been paid, and hence none to which a good title could be claimed. In North River, however, in 1899, there were 500 acres of ground which had been preempted for oyster culture, on most of which more or less planting had been done and on which the taxes were paid. The amount of ground under cultivation at the time of the survey by Winslow was 310 acres.

These waters are more like bays than rivers, their courses being very short and their mouths very wide. The mouths, moreover, are more or less filled with extensive low islands covered with tall marsh grass, separated from each other by shallow channels, and from the mainland by wider and deeper ones, which are used by the oystermen and fishermen in navigating the rivers. The supply of fresh water is furnished by seepage from the extensive marshes lying about the headwaters of the streams, and is ordinarily so limited that the currents are almost wholly due to the tide. The fresh water reaches the rivers either directly or through small shallow streams which penetrate the marsh lands, and except during very dry or very wet seasons the supply, although limited, is constant, flowing into the rivers at various points in their courses and meeting and mixing with the salt water brought up by the tides. At and near the sources the water is usually quite fresh, but the density gradually increases with the downward course of the streams until by the time the mouths are reached the salt water is so largely predominant that the effect of the fresh is scarcely perceptible. This condition explains the fact that the oyster

beds which regularly produce oysters marketable as "selects" are limited to the upper parts of the rivers. These oysters will live in pure sea water, and are not immediately killed by water which is almost fresh, but they thrive best in water which has a specific gravity of about 1.014.<sup>a</sup>

During a season of very great drought, however, the water over the beds in the upper parts of North River becomes more dense than at the mouth or at Beaufort Inlet, this peculiar condition being brought about by evaporation. The water in the upper part of the river is very shallow, but is spread out over a large area. Before it is carried past the river's mouth the tide changes, and, since there is no fresh-water supply, the same water is returned, day by day growing more salt. In August, 1900, when a density of 1.023 was noted at Beaufort Inlet, a density of 1.0248 was noted at the station near the Sunken Rock beds. It is also quite common after heavy winds from the northeast and east to find the water at the mouth of this river less dense than over the oyster beds farther up, brackish water having been blown down through Core Sound from Pamlico. This occurred on November 28, 1899, the density at the river's mouth being 1.0142, while over the planted area (station 7) it was 1.0162.

In summer the temperature of the water becomes very high, especially on days when low water occurs near midday, 93° F. having been noted above Harlow Creek in Newport, and on the experimental bed in North River at such times. In winter ice often forms over the beds, killing the oysters which are exposed or which are in very shallow water.

From tide gauges located at the Morehead City railroad wharf and at Lenoxville during the survey, and later from the gauge at the Fish Commission laboratory at Beaufort, the average daily vertical range of the tides in the harbor was found to be about 3.5 feet, with a maximum height of 5.2 feet. High winds modify to a considerable extent the height of the tides and to less degree their regularity, but usually the periods of ebb and flow take place with mathematical regularity, five hours flood being followed by seven hours ebb. The stages of the tides on the natural oyster grounds, which, in both rivers, are located about 8 nautical miles from the jetties at Fort Macon, have been found to occur two and one-fourth hours later than the corresponding stages at the latter places.

As was mentioned above, lines can be drawn in both rivers separating with a fair degree of accuracy the beds that produce a good quality of oysters from those that do not. In Newport River such a line would reach from a point just below the mouth of Harlow Creek to the oyster signal "Willis" on the opposite shore. In North River it would connect a point half way between the mouth of the small creek below

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<sup>a</sup> Fresh water has a specific gravity of 1.000; that of sea water is about 1.025.

Gillikins's windmill and Wards Creek with oyster signal "Sandy," exception being made of the beds in the upper part of Wards Creek. During wet seasons these lines would be farther down, during a period of drought farther up the rivers. The oysters from the lower beds are misshaped, ill flavored, and usually poor, and are used only by the canneries in putting up their poorest grade of stock.

The bottom in the upper parts of both rivers between the oyster beds is principally made up of black mud, although areas of hard white sand, considerable in extent, are also found. The muddy bottoms are either soft, sticky, or hard, a variable amount of sand and shell fragments being mixed with a fine, light, organic débris. The layer of mud varies in thickness from a few inches to several feet and rests upon a substratum sometimes of clay, sometimes of sand.

These extensive mud flats are the source of a considerable part of the oyster's food supply in these streams. Diatoms of many species live and multiply on the mud surfaces in such numbers that on perfectly calm days they give to the mud their yellowish-brown color, and, with the light surface layer of the mud, are easily taken up by the waves and currents and carried over the oyster beds, thousands in each quart of water. The food supply is made up of the same species of diatoms in both rivers, but during the periods when observations were made the quantity in Newport River considerably exceeded that in North River, and in the upper parts of both streams the supply was greater than in the parts below. In Newport River the food is more available to the oysters because of the more rapid currents. The food question is discussed elsewhere.

The bottom in the upper part of Newport River has a much more uneven surface than that in the corresponding part of North River, the result being that swifter currents are developed in the former than in the latter. In North River above the mouth of Wards Creek, the water is fairly uniform in depth, and in consequence becomes evenly distributed over the whole area. The general flow which takes place over the Sunken Rocks seldom attains a velocity greater than one-eighth mile per hour. In Newport River, on the other hand, in the vicinity of the Cross Rock beds, a velocity of one-half mile per hour is reached in the channels, and the oyster beds are so located that they are washed by the currents, the formation of the beds interrupting the channels and forcing the water to flow around.

#### NATURAL OYSTER BEDS.

The natural oyster beds of these rivers may best be described under two headings—reefs and tonging grounds.

*Reefs.*—Oyster reefs occur in both rivers from source to mouth, and each of the larger ones has been given a name by which it is known among the oystermen and fishermen. They are long, narrow ridges of mud and shells, the tops usually covered with a dense growth of

badly shaped oysters known as "coons." The long axes of the reefs are usually at right angles to the shore line, but a study of the conditions under which they have been produced shows that their position depends upon the direction not of the shore line but of the currents which flowed past them during their growth, the formation always making right angles with the direction of flow. The reefs are considerably higher than the surrounding areas, and at low tide for a longer or shorter period of each day they are not covered by the water. When thus exposed to the air the oysters are not only unable to feed, but are often subject to the extremes of summer and winter temperatures. The poor quality of those growing on the reefs may be due in part to these adverse conditions; their ill shape, however, is due to crowding that takes place among individuals, for although not favorable to the growth of adult oysters, the conditions on the reefs are most favorable for the attachment and growth of spat.

From a commercial point of view the oysters produced on the reefs are considered almost useless, although they have been sometimes used by the canneries in putting up their poorest stock. The chief value of reef oysters is to be found in the supply of spawn they furnish to the oyster beds located in deeper water. No matter how much the latter beds may be depleted of spawners, they are quickly restocked from the spawn of the oysters on the reefs.

A living reef, when closely examined, is found to be made up of clusters of oysters, each rooted in a substratum of soft organic mud mixed with shells and shell fragments. Between the clusters numbers of mussels, crabs, and worms are also usually present. The individual oysters of a cluster are long and narrow, and from their fancied resemblance to the paw of a raccoon, it is supposed, are known as "coons."

A cluster is a peculiar colony, representing from three to seven generations of oysters, all but two to four of them dead. Each generation becomes attached to the shells of the preceding, and thus the cluster grows wider and higher in a way which may be described by comparing it to a genealogical tree. The oldest or lowest oysters, dying either from being crowded by the oysters above or smothered by the sediment below, leave their empty shells as anchors or supports to the colony. Sediment is constantly deposited between the clusters, the bottom thus keeping pace with the upward growth of the oysters. The individuals of a cluster assume a vertical position, with mouth uppermost, and, crowded on all sides by their neighbors, they can grow only in the remaining direction—from their free ends.

On examining the immediate vicinity of a reef when it is not covered with water a strong current is found at the outer end, the direction of the flow at right angles to the long axis of the reef. A short distance either above or below the reef are more sluggish currents, either par-



LIMEKILN ROCK, NEWPORT RIVER, A TYPICAL OYSTER REEF.



A SECTION OF THE SURFACE OF LIMEKILN ROCK, SHOWING MUSSELS BETWEEN THE  
"COON" OYSTERS.





allel to the long axis or in long curves and eddies. The water at the immediate edges of the reef has still less motion. These conditions I have sought to illustrate in figure 1, on page 262. Their effect is readily seen; the oysters and shells at the end of the reef, where the swift current sweeps past, are always washed clear of sediment, while above and below the reef the conditions are favorable to the deposition and collection of the silt, which is ever present in large quantities in the water of Newport and North rivers.

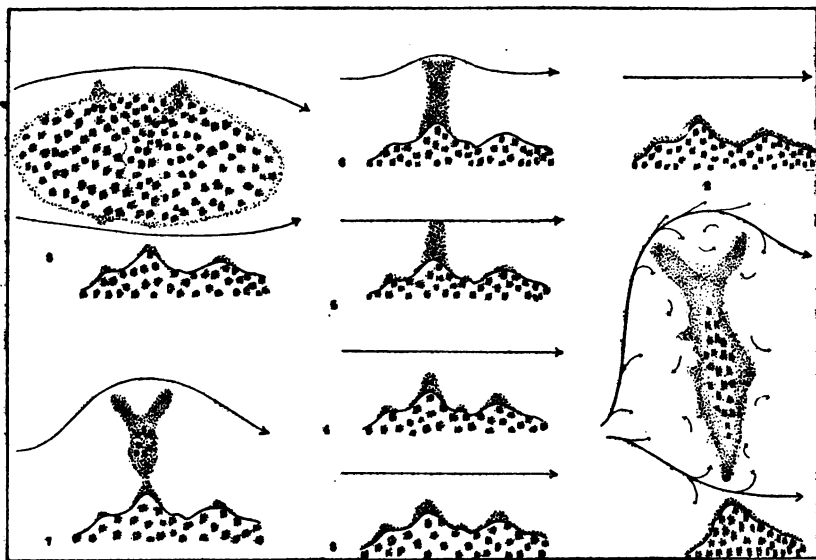
Young oysters at the end of their free swimming life attach themselves to almost any object, whether suitable or unsuitable, which happens to be at hand when the critical attaching stage is reached, but only those survive that chance to settle on hard smooth surfaces and in places practically free from sediment. The oyster at the time of its attachment is so small and delicate that it is easily smothered. For this reason, in Newport and North rivers, of the millions of young oysters that attach themselves every season, comparatively few ever come to maturity. It will thus be readily seen that the most favorable places on a reef for the attachment of spat are the oysters and shells at the end, where there is no danger of being overwhelmed by sediment, and food is carried past their mouths in constant abundance. It is very different at the sides of the reef; some of the young oysters settle where there are coatings of sediment, which kills them immediately; others succumb soon after attachment to the silt which, no longer held in suspension by the water when checked in its motion by the reef, is constantly being drizzled upon them and carried into their gills. The oysters that survive are comparatively few. The soft bottom just beyond and at the sides of a reef is gradually hardened by the oysters and shells that fall or are knocked from the top of the reef; but at the ends many of the living oysters that fall beyond the reef survive, and their shells afford places for the attachment of spat a little farther out than were before available. There are thus two formative processes at work, building more rapidly at the end than at the sides of the reef.

The manner of origin and growth of existing reefs is not only very interesting, but instructive, for in it is illustrated nature's method of preparing soft muddy bottoms for the growth of oysters; and if it can be copied by man, it is a method by which many of the now barren muddy areas in the Beaufort region and in Pamlico Sound may be made to produce oysters of good quality. The substratum of the present oyster reefs is hard, but they are, with few exceptions, surrounded by deep, soft mud, and, as I will endeavor to show, there is every reason to believe that the bottom where they now stand was once not different from the surrounding mud flats.

The banks of the rivers and harbor have always presented numerous objects with smooth, hard surfaces to which oysters might become

attached, and even now there is a more or less continuous fringe of oysters skirting the shores of the rivers and marshes. Young ones are also found adhering to shells and other solid objects which have been for some time firmly stranded on the shoals out in the rivers. Permanent objects, however, do not usually exist on the shoals; a conch shell, for instance, may lie undisturbed for weeks and become covered with spat, but sooner or later currents of unusual strength are developed by winds, and the shell with its little colony is swept away or covered up.

Starting with the fringe of oysters referred to, however, or with small colonies attached to such objects as may be stranded on the shoals, I will endeavor to show how the reefs may have been produced



Scheme illustrating the conditions near an oyster reef and the steps by which a reef may be formed. Dots represent oysters. Arrows represent water currents. Irregular line represents shore line. Groups of short lines represent marsh grass.

through the action and reaction of the conditions described. Because of their nearness to flowing water, the oysters living on the points on the shore where the river bends, or on points which project into the stream, are kept clearer of sediment and are supplied with a greater amount of food than their less fortunate fellows attached to objects in more sheltered places. To be brief, the conditions surrounding the oysters living in such exposed places are the same as those previously described for the vicinity of a reef. Figures 2, 3, 4, and 5 illustrate the effect of these conditions in producing at first a collection of clusters on the projecting points, then an extension of the clusters, forming a bar of oysters toward the current channel. As this bar increases in length it causes a gradual slackening of the inshore currents, with

consequent reduction and the final disappearance of the adjacent oysters on shore. The growth of the bar continues, finally reaching the current channel, where its further growth results in forcing the current to bend away from the reef and cut a new channel farther out. The currents thus no longer flow straight past the end of the reef, but strike it at an angle less than  $90^{\circ}$ , making new conditions, under which the most rapid growth of oysters, at right angles to the flow of the displaced currents, is no longer in the original direction of the reef. A branching of the reef at its end is thus brought about, as is shown in figures 6 and 7.

As the reef continues to grow in length, its damming effect upon the volume of water, which must twice each day find its way up and down the river, increases, and there comes a time when the reef is no longer able to force the entire stream around its outer end. A break must occur at some point in the reef, and in nearly all cases in Newport and North rivers this has taken place at a point a few yards from the shore. Reefs originating from points in the river would of course grow from both ends, and a break in their length would not be likely to occur, since wide open ways for the water are left at either end.

Reefs of recent formation are low and very narrow in proportion to their length, and clusters of living oysters are found evenly distributed over their areas. The patches of oysters in the center, however, in time are covered and killed by the sand, mud, and shells washed up and deposited upon them by the waves, the reefs thus gradually becoming higher and wider (fig. 1). With the accumulation of this debris year by year the high-water mark is gradually reached. Successive catches of spat, which spread over the top of the reef, are repeatedly covered, and finally a plane is reached so near high-water mark that the period of time during which the oysters are covered by water is too short to allow them to collect the minimum amount of food required. Examples of such high, permanently dead reefs are found in both rivers. They are conspicuous objects on clear days, for the bleached shells and white sand of which they are composed reflect the light and give an appearance of dazzling whiteness.

Grass finally takes root on the high oysterless patches on the old formations, and then the "white" reefs begin their transformation into "green" reefs. The grassy islands found in various places in the rivers are usually very low and marshy, with only a fringe of living oysters around them, but there are a few which, in addition to the fringe of oysters, have a hard shelly center. This character, together with their position in the rivers, suggests their probable origin from oyster reefs. When a reef is young and low, its growth in length is rapid until the limits are reached. Its upward growth is restricted to the height at which the oysters are able to catch sufficient food. Each reef, however, acts as a dam in catching and holding extensive areas

of sediment both above and below, and year by year these areas become higher and higher, until they finally reach the height of the reef. Grass then spreads over the whole and an island is formed with a width greater than the original length of the reef from which it started (fig. 8).

The conditions of some of the typical living reefs of Newport River are shown in the table below. The figures represent what was found on a square foot of the surface on the highest part of each reef. A photograph also is reproduced, which gives a better idea of the appearance of the oysters and their distribution on the reef.

Name.	Oyster clusters.	Adult oysters.	Spat.	Shells.	Mussels.	Mud crabs.
Cross rock.....	22	43	108	60	37	5
Green rock.....	21	32	137	26	97	2
Limekiln rock.....	19	47	120	50	28	4
"A" rock.....	21	55	163	52	49	4

In addition to the above, worms are abundant in the mud about the roots of the oyster clusters, and an occasional clam is also found. Barnacles cover the shells of oysters wherever found. On the reefs near the mouths of the rivers, sea anemones and a species of shrimp are abundant.

*Tonging grounds.*—The natural oyster beds from which salable oysters are annually obtained by the tongers lie in the upper halves of the rivers and in certain similar localities in their principal head-water tributaries. Those tributaries which join the lower halves of the rivers have no tonging grounds of importance, but contain only such reefs as those found in the parts of the rivers into which they flow.

Every tonging ground is associated with a reef. They are found in some instances apparently independent (Lawtons Rock in Newport and Sunken Rock in North River), but in these cases the reefs have been cut down and hauled away for use as fertilizer on farm land or in the manufacture of lime. Each tonging ground consists of a strip of hard or sticky bottom of varying width, and extends along either one or both sides of a reef below low-water mark. The hardness of the bottom on these strips is in nearly every case due to the shells that have fallen from the adjoining reef. Such portions as have been sufficiently hardened to support single oysters at the sides of very young reefs or along those surrounded by very soft deep mud are too narrow to be of commercial value, but in the vicinity of some of the old reefs the tonging grounds are acres in extent, that around Sunken Rocks in North River, for example, containing 40 acres. Natural agencies only (winds, waves, rain, and ice) are at work in scattering shells and oysters over the bottoms adjacent to young reefs, and they work very slowly, but as soon as the hardened areas become sufficiently large to produce single oysters in considerable abundance the oystermen are attracted to them and their growth becomes more rapid, for



TURTLE ROCK, NEWPORT RIVER, SHOWING A SECTION OF TONGING AREA. (FROM PHOTOGRAPH TAKEN AT VERY LOW TIDE.)



A TYPICAL TONG BOAT, SHOWING TONG MEN AT WORK.

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in tonging oysters and returning the cullings to the bed the soft bottoms beyond the hard are rapidly filled with shells.

Aside from the few oysters annually carried from the reefs by waves and ice and deposited upon them, the tonging grounds are stocked from the young free-swimming oysters that attach themselves to the exposed shells. The amount of spat caught by the shells varies from year to year, the climatic conditions at times being such that practically no catch is made. From the results obtained in the planting experiments carried on during 1900, 1901, and 1902 it appears that spat become attached in greatest abundance when the specific gravity of the water is from 1.010 to 1.017. In Newport River a dry season brings about the most favorable conditions, but in North River the best results are obtained when the amount of rainfall is greater than usual. The condition of the shells, too, has much to do with the amount of spat that becomes attached. If the shells are covered with sediment or coated with "slime" the oysters are killed, their structure and size at this stage being such that they are easily smothered.

The sediment that settles upon shells in quiet water is easily removed by wave motion during high winds, and it probably has little effect upon the catch of spat during a season, but when "slime" accumulates it is not so easily removed. By "slime" is meant any growth that brings about a foulness of the surface of the shells. This may be a vegetable growth (diatoms or algæ), or it may be brought about by animals (sponges, bryozoa, hydroids, etc.). It is produced most rapidly and abundantly when the water is salt, the plants and animals thriving best in pure sea water, and it is effectively removed when the water becomes brackish. On this account the shells on the beds situated in the upper parts of the rivers are usually quite free from slime and a good catch of spat is annually counted upon, but those on the beds lower down often become very foul and worthless as spat collectors.

Oysters grown on the tonging grounds owe their superiority to reef oysters to the fact that, not being crowded, each oyster not only has room for normal growth but is well supplied with food. As has been mentioned in other places in this report, the food resources of these rivers are adequate for many times the number of oysters now produced, provided the oysters do not lie too close together. In places on the tonging grounds spat often covers the shells when they happen to be unusually clean, and the result is bunches of oysters in which the individuals are just as ill-shaped and unsalable as those on the reefs. The water flowing past such a bunch of oysters is the same in amount as that which supplies an oyster growing singly, and contains the same amount of available food, but in the one case several mouths share what, in the other, is available for one. It is not surprising, therefore, that oysters growing in clusters, whether found on reefs or on tonging grounds, are usually poor.



The depth of water over the tonging grounds varies at low water from a few inches to not more than 7 feet, so that dredges can not be used. The size of the beds, however, is not such as to attract dredgers, only a few weeks being required after the season opens for the tongers to catch the stock which has grown during the year. Before the opening of canning establishments at Beaufort, the beds were much more prolific than now, the usual daily catch at that time being from 25 to 40 bushels of oysters. The increased demand made by the canneries led to the over-fishing of the beds, and at the time of the survey the daily catch for a tong boat had been reduced to 8 or 10 tubs.<sup>a</sup> In taking this quantity of oysters it was necessary for the oystermen to handle an immense quantity of cullings, as is shown by the results of tongings made on a few of the typical beds in Newport River by the surveying party. In gathering 1 peck of salable oysters, there were handled on the bed below Limekiln Rock 160 small oysters and spat, and 1,060 shells; on the bed above Limekiln Rock, 154 small oysters and spat and 536 shells; on the bed below Cross Rock, 82 small oysters and spat and 400 shells. The beds in North River are in about the same condition.

The oystermen do their tonging from small sailing skiffs 15 to 25 feet in length. Each skiff is usually manned by two persons—a man to tong and a man or a boy to cull. When the bed is reached the sail is furled, and laid, with the mast, in the bow of the skiff. The tonger works from the stern, dumping the stock, just as taken from the bed, upon a wide culling board laid across the boat amidships. The culler, armed with a short stout stick, goes over the stock, separating the salable from the undersized oysters, shells, and other débris, returning the cullings to the bed and throwing the oysters into the boat. The tongs used by the oystermen are made by local blacksmiths and carpenters, with shafts from 10 to 16 feet in length and heads containing 12 to 16 teeth. The implements and the methods of using them are shown in various photographs reproduced in the report.

The price received by the tongers for the oysters taken to the canneries is seldom more than 18 cents per tub, and it is often less. When "raw houses" are running, however, the price for the best stock is higher, 25 to 40 cents being received. The tongers often carry their catch to the canneries in their skiffs, but during the busiest part of the season the canneries send large sharpies, known as "buy-boats," to the beds to buy from the oystermen. Less time is lost in this way, many of the tongers remaining over night in the tonging region, ready to begin work at sunrise.

The largest and best single oysters produced in the Beaufort region come from an area in North River lying above Jacks Island Reef, out-

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<sup>a</sup>The "tub" is the standard measure adopted by the canneries, and holds 1½ bushels.

side the regular tonging beds. The oysters are not sufficiently numerous on this area to be tonged in the ordinary way, but during very calm weather when the water is perfectly clear, the oystermen pole their boats about over the bottom, picking up the oysters one by one as they see them, using for the purpose tongs with very narrow heads, locally known as "nippers." The supply of oysters on this area is very limited, and they bring from 40 to 75 cents per bushel. In Newport River single oysters are found only on the tonging grounds, the bottom between the beds being too soft to support them.

The tonging grounds of both rivers produce clams in abundance, and when the oyster season is over or when tonging for oysters becomes unprofitable, the beds continue to be worked for clams. Mud crabs, barnacles, worms, snails, and boring sponges are also found with the oysters, but they are not usually in sufficient abundance to be detrimental.

The quality of the oysters produced on the tonging beds is not the same from year to year, but varies with the climatic conditions, which affect the two rivers differently. For a few years previous to the survey the beds of North River had the reputation of producing oysters much finer than those grown in Newport, but this was reversed in 1899, since which time the Newport oysters have been considered the best in every particular. During this period the food supply in Newport has been richer than that of North River, and the difference has been enough to account for the difference in result.

The food of the oysters on the Sunden Rock beds and the richness of the food supply in the water over them, as shown by a few examinations made during the summer of 1900, is given in the table which follows.\*

*Food found in the stomach of an oyster  $3\frac{1}{2}$  inches in length, and in a liter (about 1 quart) of water.*

	<i>Melosira sculpta.</i>	<i>Pleurosigma spencerii.</i>	<i>Eupodiscus radiatus.</i>	<i>Navicula didyma.</i>	Total.
Oyster .....	8,057	485	1,058	5,312	14,912
Water .....	3,621	7,590	1,178	1,712	14,096

During the survey (November 23 to January 6, 1900) the density of the water over these beds averaged 1.0189 at surface and 1.019 at bottom, high tide; at low tide, the reading was 1.0163 at both surface and bottom. During the summer of 1900 the average was as follows:

*Density over Sunken Rock beds.*

Month.	High-tide surface.	Low-tide surface.
May.....	1.0178	1.016
June.....	1.0212	1.0206
July.....	1.0243	1.0238
August.....	1.0246	1.024

\* This table should be compared with that for the Cross Rock Beds, on page 289.

The future history of the oyster beds of these rivers is likely to be similar to the past, periods of productiveness followed by longer or shorter intervals during which the oysters are not salable. These changes may be brought about by a combination of factors, but the one having the greatest influence is probably the specific gravity of the water.

#### PLANTED GROUNDS.

Oysters were first planted in the Beaufort region about the year 1840, a Mr. Hardesty having bedded a small quantity during that year at the head of Harlow Creek. Many such plantings were made from this time until about 1859, and many of the beds then planted have continued to the present. The idea of the planters was not to raise oysters for commercial purposes, but for their own use, as is shown by the name which they gave to their beds—"oyster gardens"—a name, by the way, which has been retained throughout the State for all planted grounds.

During the survey the Hardesty bed was examined on several occasions and several bushels of the oysters were used on the *Fish Hawk*. They were large, well shaped, and in excellent condition. The area of the planted ground is necessarily small, being situated in a bend in the creek about  $1\frac{1}{2}$  miles from its mouth. The bottom is hard now, although originally it was probably quite soft, like the bottoms above and below the bed. The density of the water is subject to great and rapid fluctuations, the supply of salt water, coming from Newport River and at times from the Neuse through the "Club Foot" Canal, being greatly influenced by the wind. An abundant supply of fresh water flows in from the extensive marshes lying all about. The minimum density noted over the bed was 1.0028 and the maximum 1.0164; the depth of the water is from 4 to 7 feet. It is the supposition of the oystermen that the oysters here are fattened by food which comes with the fresh water from the marshes; examinations did not confirm this view, however, but showed that the food comes from the same salt and brackish-water sources that supply the oysters of Newport River. This bed has been mentioned because it is an example of a continuously successful one, situated in a place which has no more to commend it to an oyster planter than numerous other larger areas in Newport and North rivers.

The following table, compiled by Mr. C. H. Stevenson, shows the number and acreage of the oyster gardens made in the waters of Carteret County since 1872. The number of beds made before this date can not be accurately ascertained, since it was not then necessary to have the entries authorized by law, and no record of them has been kept by the clerks of the court.



TONG BOATS IN PORT.



A "BUY BOAT" ANCHORED TO BUY OYSTERS FROM THE TONGERS.



*Acreege of oyster gardens in Carteret County.*

Year.	Num- ber.	Acres.	Year.	Num- ber.	Acres.	Year.	Num- ber.	Acres.
1876 .....	1	7	1884 .....	96	911	1892 .....	77	763
1877 .....	1	9	1885 .....	34	324	1893 .....	19	184
1878 .....	8	74	1886 .....	53	496	1894 .....	4	38
1879 .....	1	8	1887 .....	28	273	1895 .....	1	10
1880 .....	2	17	1888 .....	4	40	1896 .....	39	367
1881 .....	2	20	1889 .....	108	1,042	1897 .....	20	182
1882 .....	5	47	1890 .....	162	1,512	1898 .....	2	20
1883 .....	4	37	1891 .....	157	1,467			

Total, 828 beds, aggregating 7,848 acres.

Of this total, 107 beds were located in Newport River, and even a larger number in North River. Nearly every farmer, oysterman, fisherman, and business man living in the vicinity of these waters has at some time made an entry of ground and planted some oysters. In 1899, however, the beds in Newport River had all been abandoned, and in North River there were only about 30 beds on which the taxes had been paid. In the entire county the total number of beds held at that time was 130, covering 1,099 acres.

The failure of the attempts at oyster culture thus far can not be attributed wholly to inexperience on the part of the planters, for the most extensive efforts in Newport and North rivers have been the work of men from the North who had had experience in oyster planting. The methods suited to conditions in the North, however, may not have been adapted to those in North Carolina. Mr. J. N. Ives, from New Jersey, planted extensively in Newport River in 1875 and in North River in 1891. The oysters in North River lived, but were not superior to those raised on the natural beds. Oystermen took up the oysters from his beds the second season after they were planted and sold them to Mr. Ives, who was then operating a raw house in Newbern. The oysters on his Newport bed thrived for one season, but died in great numbers during the second. Mr. E. L. Gandy, also from New Jersey, made an extensive plant in Newport River, but the oysters remained poor and unsalable year after year, and he finally abandoned the bed. The ground selected was excellently adapted to growing oysters, and Mr. Gandy attributed his failure to too great variation in the density of the water. He also thinks there are more oysters in the river than can obtain a sufficient amount of food.

Various reasons are given by the oystermen for the failure of planted oysters, most important of which are the following:

(1) Insecurity of title, depriving the owners of protection against trespass.

(2) A high rate of mortality among planted oysters.

(3) Failure of the planted oysters to become fat during the season when they should be marketed.

The first of these difficulties can be eliminated by the enactment and enforcement of laws more favorable to oyster culture. The second and

third are, in my judgment, due to the location of the planted beds in places where the water is almost universally more dense than is favorable to the growth of salable oysters, and can also be eliminated to a considerable extent in future plantings, if it be made possible by law to preempt the areas not occupied by oysters in the vicinity of the natural beds. It has been necessary, hitherto, for the planters, in order to avoid litigation and to receive legal protection, not only to take up no natural oyster bed, but to keep far from such grounds. The result has been that most of the planted beds in both rivers have been located below the lines marking the limits of natural beds regularly producing salable oysters, and where the conditions are too seldom favorable to make planted oysters a profitable investment.

The conditions on the areas occupied by the planted beds are, however, sometimes favorable to the production of good oysters. In 1899 the oysters on the beds abandoned by Mr. Gandy became fat, and furnished employment for several tongers throughout the season. It was estimated that there were enough oysters removed from his beds at this time to have repaid Mr. Gandy for all the expense incurred in planting, for the oysters were large and in excellent condition, bringing from 40 to 60 cents per bushel. In 1895 and 1896 planted oysters in North River were valuable, and there have been other years when it was profitable to take them up.

That the failure of oyster planting in these waters is not due to a lack of proper food was demonstrated by examination of the water collected simultaneously from natural and planted beds. The results of this examination are shown in the food tables on pages 272 and 289.<sup>a</sup>

The enemies of the oysters of North Carolina are not numerous when compared to those with which the oysters in the North have to contend. Starfish do not visit the beds at all and "drills" do no appreciable damage. There is, however, a parasitic worm (*Bucephalus cuculus*) common in the oysters on both the natural and planted beds in the Beaufort region, which may possibly have been accountable for the high death rate among planted oysters during certain years. It is not a parasite peculiar to the oysters of Beaufort, but is found in oysters from the beds in Pamlico Sound, Chesapeake Bay, and South Carolina waters.<sup>b</sup> The exact effect on the oysters is not known and is a subject which merits investigation. The way in which the oysters become infected with the worm is also a subject about which very little is known, but this probably occurs when the oyster is feeding, the larvæ coming into the shell with the stream of water drawn in by the gills, and fastening themselves to the soft parts of the oyster. Once attached, the parasite grows rapidly, soon filling the body of the oyster with its offspring and completely riddling the tissues with holes. It seems also to spread from one oyster to another—at least,

<sup>a</sup>See also page 292.

<sup>b</sup>I am indebted to Dr. D. H. Tennent for this information.

infested oysters are much more numerous on certain beds than on others.

The parasite may not be the direct cause of the death of oysters it infests, but they are necessarily much less vigorous and less able to withstand unfavorable conditions. The fact that the death rate on planted beds is much higher than on the natural beds may be due to the combined effect of the parasite and the less favorable physical conditions.

As uniform conditions exist throughout the region in each river that includes the greater number of planted beds, and as similar methods have been used by all the planters, for convenience in description, one bed in each river may be taken as a type.

Mr. E. L. Gandy selected ground near the middle of Newport River between the mouths of Harlow and Oyster creeks, and planted about 800 bushels per acre of uncultured stock, tonged mostly from the beds in Harlow and Core creeks. The bottom at the place selected, composed partly of clay, partly of sand, is covered with a layer of soft, organic mud of varying thickness; a pole can be thrust into it to a depth of 6 to 15 inches. The water varies in depth from 3 to 9 feet at low tide, being deepest in the main river channel, which runs through one part of the bed. A velocity of 0.8 mile per hour was noted over the bed in the main channel at certain stages of the tide, and velocities of 0.5 and 0.6 mile per hour are common over the shallower parts of the ground. The density of the water varies greatly, being much lower on low or falling tide than when the water is rising or high. The drainage of fresh water from the vast area of low marsh lands at the head of the river and along the banks of Harlow Creek mixes with the salt water of the river and is carried over the bed as the tide flows out. Four density stations were located over this area. The first (No. 1), in the channel between Crab Point and the mouth of Core Creek, No. 2 near the north bank of the river and near the mouth of Oyster Creek, No. 3 opposite the mouth of Harlow Creek, and No. 4 south of the end of White Rock. The following tables give the average density at these stations, as determined by observations made at high and low water, from October 6 to November 23, 1899, and at two of these stations from May 1 to August 31, 1900. No corrections for temperature have been made:

*Average densities over oyster bed in Newport River, planted by E. L. Gandy.*

OCTOBER 6 TO NOVEMBER 23, 1899.

Station.	High tide.		Low tide.	
	Surface.	Bottom.	Surface.	Bottom.
1.....	1.0182	1.0187	1.0164	1.017
2.....	1.0176	1.0177	1.0156	1.0156
3.....	1.0163	1.017	1.0123	1.0156
4.....	1.0168	1.0169	1.0146	1.0166



*Average densities over oyster bed in Newport River, planted by E. L. Gandy—Continued.*

MAY 1 TO AUGUST 31, 1900.

Month.	Station 1.		Station 4.	
	Low tide.	High tide.	Low tide.	High tide.
May.....	1. 0171	1. 0198	1. 016	1. 0184
June.....	1. 0192	1. 020	1. 0172	1. 0186
July.....	1. 0212	1. 0214	1. 0204	1. 0219
August.....	1. 0224	1. 022	1. 021	1. 0222

The conditions existing at the time when the data for the first table were collected, were probably as favorable for oyster culture as are ever found in Newport River, and, as before stated, the planted oysters were in excellent condition, but even then the density over the lower part of the beds (stations 1 and 2) was too high for the best results. The gradual increase in density over the planted area during the following summer was due to the excessive dryness of the season, the fresh-water supply which usually comes from the low country about the head of the river being stopped altogether.

The food of oysters on the planted beds consists of the same species of microscopic plants that constitute the food on the natural beds, but numerous examinations during the summers of 1900, 1901, and 1902 show that the supply is not as abundant over the planted beds as it is farther up the river, and not of exactly the same quality. The following table, made from records of examinations of the stomach contents of medium-sized oysters from Mr. Gandy's beds and of water collected over the same in 1900, may be compared with the tables on page 289, which show the amount and quality of the supply over the natural beds.

*Food found in stomachs of oysters from E. L. Gandy's beds in Newport River.*

	Eupodiscus radiatus.	Melosira sculpta.	Pleuro- sigma spon- serif.	Navicula didyma.	Total.
One oyster.....	847	1, 922	6, 990	642	10, 401
Water (1 liter).....	1, 429	2, 272	9, 365	.....	13, 066

The most striking difference between Mr. Gandy's beds and the natural tonging grounds is to be found in the animals that live thereon. The variety and richness of the fauna on the planted beds is remarkable. Every tongful of oysters and shells brought up is conspicuous with bright colored sponges and leptogordias, which, together with many other animal species, are known to the oystermen as "moss." Four species of sponge are found, the most abundant being a boring sponge (*Cliona*), two leptogordias (yellow and red), three species of ascidians, two bryozoans, several species of worms, three crabs, and two drills, also oyster-fish and barnacles. The extreme saltness of

the water is the factor that makes it possible for many of these animals to live on the planted beds, and a reduction of the density but a few points would effectually exclude nearly all of those mentioned. Very few of the coinhabitants are directly injurious to the oysters, but they produce a foulness which catches sediment and prevents the attachment of spat. Drills destroy a few young oysters, and the boring sponge makes the shells brittle.

The oyster garden of Mr. J. W. Ireland, planted in 1891, may be taken as representative of the planted beds in North River. It lies just off the mouth of Roberts Bay in the region containing the greatest number of plantings, and has been as successful as any in the river. Here, as in Newport River, all the planted beds are below the area on which the productive natural beds are found. The bottom, a black, sticky mud, is very light and soft, and is composed of fine organic débris mixed with grains of sand and swarming with living diatoms. Below it gradually grows firmer and harder, the proportion of sand becoming larger, but in nearly every place not covered with shells or oysters, an oar can be thrust into it to a depth of from 9 inches to 2 feet. The water over the bed is about  $3\frac{1}{2}$  to 4 feet deep at low tide. The currents over this, as over all of the planted areas, seldom develop a velocity of more than one-third of a mile per hour. The specific gravity of the water is quite high, making possible an even denser growth of marine animals on the planted shells and oysters than was noted on the Newport planted oysters. The average density at stations 2, 3, and 7 during the period of the survey (November 23, 1899, to January 6, 1900) is given in the table which follows:

*Average densities over oyster garden in North River planted by J. W. Ireland.*

Station.	High tide.		Low tide.	
	Surface.	Bottom.	Surface.	Bottom.
2 .....	1.0221	1.0227	1.0172	1.0173
3 .....	1.0206	1.0207	1.0181	1.0182
7 .....	1.0197	1.0199	1.0169	1.017

For the summer months of 1900, 1901, and 1902 the density shown in the food tables on page 289 for the experimental bed may be taken as representing Mr. Ireland's bed, for the northeast corner stake of the former marks the southwest corner of this oyster garden.

The method of planting used by Mr. Ireland was the same as that employed by all the North and Newport River planters. Unculled stock was brought down from the natural oyster beds at the head of the river, just as it was tonged, and spread broadcast over a portion of the bottom, stakes being set so that the same ground should not be

planted twice. The work was carefully done, but no estimate was made of the amount planted per acre. The bottom was in no way prepared for the oysters. They were placed directly upon it, the expectation being that the quantity of shells would be sufficient to prevent the oysters from sinking too deeply into the mud. It is evident, however, that the oysters were as likely to support the shells as were the shells to support the oysters, and from the number of black mud blisters which mark the interior of the shells and the frequent occurrence of completely "mudded-up" oysters, it seems that the bottom was too soft and should have been hardened before the planting.

At the time of the survey, however, there were not only on Mr. Ireland's, but on many of the planted grounds, numerous places where oysters were growing. The condition of Mr. Ireland's beds in two places is shown by the following table, in which is given the amount of cullings taken while tonging 1 peck of salable oysters from each:

*Amount of cullings while tonging 1 peck of salable oysters on J. W. Ireland's bed.*

Station.	Small oysters and spat.	Shells.	Mud crabs.	Oysters and shells with sponge.
1 .....	111	440	14	70
2 .....	135	816	9	168

During the month of November the oysters were watery and poor, but in December they became plump and white, and until April were in a marketable condition, although early in December those on Mr. Ireland's bed, as on all the natural and planted beds in the lower part of the river, became affected with the "green gill" (see below). The amount of food available for the oysters on this and the other planted beds in the immediate vicinity is shown in the tables on page 290, but it compares unfavorably with the amount available for oysters on the natural beds, as will be seen by comparison of this table with the one on page 267.

#### "GREEN GILL."

Soon after beginning work in North River in 1899, the "coon" oysters at the mouth of Goose Creek Bay began to show a green color in their gills. In a week or so this was noticed in the oysters in Wards Creek also, and shortly afterwards those on the planted beds in Roberts Bay began to be affected. The color was very faint at first, but gradually deepened until the gills were the exact shade of a mass of *Oscillaria* filaments (a blue-green alga). Examination showed that among the cilia of the gill filaments and in the interfilamentary spaces, enormous numbers of a small, disk-shaped, granular, single-celled, blue-green alga were crowded. In this position they were growing and multiply-

ing with remarkable rapidity, and the oysters were utilizing the overflow for food, for those on the affected beds immediately became fat and their stomachs were full of the plant that was living in their gills. In no case were the plants found in the tissues of the oysters, but always external.

Only twice before do the oyster men remember that the "green gill" has affected North River oysters, and they state that at those times the whole river bottom was coated with green slime. Others said they had noticed that the "green gill" occurred when the leaves fell from the trees while yet green. In the present instance I examined the bottom of the river carefully and not only failed to find a coating of green slime, but failed to find the plant, even in small numbers, and the color in this case could not have come from chlorophyl bodies freed from decaying leaves, for they are different in both color and structure; but notwithstanding the fact that I failed to find a green scum on the river bottom, I was told the following summer that it was there and had been the cause of the "green gill." The plant is, I believe, a single-celled blue-green alga, which finds very favorable conditions for its growth in the gills of the oyster. The species I have not been able to determine. The affected oysters were used frequently on the *Fish Hawk* and, aside from their color, could not be distinguished from oysters not so affected.

#### THE SPAWNING SEASON OF BEAUFORT OYSTERS.

During the whole of the time occupied in the survey of Newport River in 1899 the oysters from the natural beds contained mature eggs and sperms in their gonads, although the number of eggs that could be taken from an individual female was not large. In North River females with mature eggs were taken until early winter, December 18 being the latest date on which artificial fertilization was successfully accomplished, but the gonads were very small, absorption having begun in October. The fact that mature eggs and sperms were present in the reproductive organs of some of the oysters at this late date does not mean that spawning continued to take place; and had they been discharged into the water their development would doubtless have been prevented by the cold.

The earliest date during the season (1900) at which eggs were successfully fertilized was the 16th of April. The oysters found at this time with mature sexual product were few, but their reproductive organs were being rapidly developed, and on May 2 nearly every oyster taken from the natural beds was ready to spawn. While it was possible to get mature eggs from the middle of April to the middle of December, the actual spawning season probably does not begin before the 1st of May, and it probably ends in November, although young oysters have been known to attach to shells in May, June,

July, August, and September, and doubtless would have attached in October and November had shells been planted during these months. Spawning takes place most actively during June and July. The gonads during this period are very large and contain the reproductive elements by millions.

#### SURVEY OF PAMLICO SOUND.

The commercial importance of Pamlico Sound as an oyster producing region has been recognized only since about the year 1889. Previous to that time the oysters produced in Chesapeake Bay and farther north were so plentiful and the price so low that it was not thought profitable to handle the North Carolina stock. In 1889, however, owing to the scarcity of oysters in Chesapeake Bay, the Baltimore canners and dealers in raw oysters established branch houses at various points on the North Carolina tide-water coasts, shipping their stock to Baltimore, where it was sold as Chesapeake oysters. This had a very marked influence on the North Carolina oyster industry, for with the canneries came the Chesapeake oystermen, introducing modern methods of oystering. The short-handled, wooden-headed tongs, which were at that time the only implements used by the native oystermen, were replaced by the more efficient tongs with iron heads and long handles. Of more importance still, dredging was introduced, and it has been through the dredgers mainly that the industry has been developed. Before they began operations beds located farther than 2 miles from shore were practically unknown, but now such off-shore grounds are the principal source of the Pamlico product. The following data, furnished by Mr. Stevenson, show the fluctuations in the industry since 1887:

In 1887 the yield of oysters was about 100,000 bushels for the State, and this amount had seldom been exceeded. In 1890 the North Carolina oystermen alone sold 914,130 bushels. No record was kept of the amount dredged by vessels hailing from Maryland, Virginia, Delaware, and New Jersey (about 250 in number) during the same year, but it was probably not less than 1,800,000 bushels, a single one of these vessels having been reported as taking 20,000 bushels. This rich harvest for the more experienced nonresident oystermen led to the enactment of laws preventing nonresidents from dredging and limiting the season when dredging could be carried on at all. The result was a very great decrease in the catch during the years immediately following, 60,000 bushels being the total amount reported in 1893-94 and 40,000 bushels in 1896-97.

The season during which dredging could be carried on was lengthened in 1897, with the effect of increasing the catch that year to 858,818 bushels. In 1898-99 dredging and tonging were carried on extensively from the beginning to the end of the open season (December 1 to May 1); 115 dredge boats, aggregating 990 tons and employing 750



WINDROWS OF SHELLS AND SAND ON THE MARSHY SHORE AT SHELL POINT,  
HYDE COUNTY.



MUSSELED OYSTERS FROM SWAN QUARTER BAY.

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men, and 950 tong boats were engaged, and more oysters were caught than ever before in the history of the North Carolina industry. Many new and extensive beds were discovered, and the supply of oysters seemed to be inexhaustible; 2,450,000 bushels were taken, 900,000 of which represented the catch of the tongs.

Increased preparations were made for the season of 1899-1900, but instead of conditions such as had existed the previous year, it was found that oysters were very scarce and difficult to dredge, and only those oystermen who had had considerable experience were able to make a profit. The total catch during the entire season was about 1,900,000 bushels, of which the tongs caught nearly half. On the beds where a dredger could take 400 to 800 tubs of oysters per day during the season of 1898-99, the same men with the same equipment in December, 1900, could average but about 50 to 100 tubs.

The oystermen had different ideas as to the cause for the shortness of the crop, some attributing it to overfishing of the beds during the breeding season of the oyster, others claiming that the oysters had been killed by the severe storms which occurred in August and October of 1899.

At the request of Prof. J. A. Holmes, the *Fish Hawk* was ordered to the section in Pamlico Sound where the greatest damage was reported, with instructions to ascertain the exact cause or causes of the diminished catch. It was hoped that the investigation would suggest some practical means for rapidly replacing exterminated oysters.

The storms mentioned above were the most violent and destructive that have visited the coast of North Carolina for many years. In each case the wind blew chiefly from the southeast, producing very heavy seas in the wide, unbroken stretch of Pamlico Sound, which lay in its path. The huge waves broke all along the western and northern shores of the sound, but, as a glance at a map will show, the Hyde County coast was exposed to their greatest fury.

#### SWAN QUARTER BAY.

*General conditions.*—Section 16 of the Winslow survey, extending from Bluff Point on the east to Rose Bay on the west, was therefore selected for first investigation.

The survey of this section, which lasted from January 22 to February 28, was conducted in very much the same way as those of Newport and North rivers, except that in the present instance only those beds were surveyed and charted which are situated in places most exposed to the action of storms, namely, the public grounds numbered on Winslow's charts 38, 40, 41, 42, 46, and 48. Signals were erected on shore, the same sites being selected when possible as were occupied by the signals used in 1887-88 by Winslow. During the survey the *Fish Hawk* was anchored in Swan Quarter Bay, the work being



mainly done from launches. The State oyster police boat *Lillie* assisted in making the examinations of the oyster beds by towing the dredge boat *Varina* over them. Since Winslow's survey numerous extensive beds of oysters have been discovered in the deeper water of the section, and some of these also were examined.

The *Fish Hawk's* work showed that while the beds which were known and charted by Winslow have probably not been reduced in area, they have been so depleted of oysters and cultch that they yield a much smaller percentage of oysters than formerly, some of them practically nothing. The beds which have been furnishing the greater part of the oysters in more recent years are located over 2 miles from shore and have been discovered recently by the dredgers. Inquiries made by Mr. Stevenson showed that the beds now known in the section cover an area ten to twenty times that of the beds charted by Winslow, making the present area of the natural beds of Hyde County from 18,080 to 36,164 acres. Winslow gives the possible area of bottom in section 16 available and suitable for oyster culture as 38,315 acres. At present it is not possible to confirm this estimate, but determinate results are hoped for from experiments now being conducted by the State of North Carolina and the United States Fish Commission with reference to the possibilities of oyster culture, either private or public, on the various kinds of bottom and in the depths of water afforded by Pamlico Sound.

*Damage by storms.*—All along the marshy shore from Shell Point to Winslow's signal "Sherman" was found an unbroken line or windrow of large bleached oyster and mussel shells, the hinges of which were still intact. These, together with banks of sand, had been thrown up on the edge of the marsh land by the waves as they broke on the Shell Point oyster beds, and the same evidences of the violence of the waves were found on the beach at Bluff Point and various other exposed shores. The few hundred bushels thus thrown entirely out of the water would not, of course, have been a serious loss to the beds, but they serve to give some idea of the effect of a severe storm on a bottom composed of shifting material, and they are no doubt but an insignificant number compared to those covered by the bottom as it was torn up and carried before the storms. The oysters that were entirely covered with sand perished immediately, and those only partly sanded over eventually died. It was very common in February, when dredging, to bring up open-hinged oyster shells which still contained the body of an oyster nearly or quite dead. Such individuals were always so poor as to be hardly recognizable as oysters; their bodies were shrunken and their mantles and gills clogged with the sand and mud which had oozed in with every attempt to feed. Their stomachs were entirely empty. The presence on the oyster beds of empty shells in which the hinge was still unbroken was taken as evidence of

the recent death of the oysters, and the abundance of such shells in certain localities indicated that the rate of mortality during the period immediately preceding the survey had been very high. The greatest proportion of hinged shells to living oysters was found on the beds off Shell Point, south of Bird Island, east of Great Island, and off Juniper Point, while in sheltered places like Swan Quarter Bay and Swan Quarter Narrows the number of hinged shells was small. These facts indicate that the oystermen were right in attributing to the storms much of the damage sustained by the oyster beds.

*Effects of dredging.*—In 39 hauls made with dredges at various places on the public dredging ground (No. 48) which lies just off Shell Point, the average number of marketable oysters taken per haul was 4; of hinged shells also 4, while 8 and 5 were the average numbers of small oysters and spat, respectively. These figures show very strikingly the depleted condition of this ground as the result of too close dredging. The damage done by the storms is also indicated, fully 23 per cent of the oysters having been sanded.

Twenty hauls were made with the dredge on the dredging ground (No. 46) southeast of Swan Quarter Island, and showed the bed to be in much the same condition as No. 48. The oysters were much scattered, but the size of the productive area was found to be many times that shown on Winslow's chart, much growth evidently having taken place since 1888. The per cent of empty hinged shells was somewhat less than that on the Shell Point bed, the number representing about 14 per cent of the living oysters.

Public ground No. 42, which lies in the Swan Quarter Narrows and west of Great Island, is well protected from storms, and presented conditions which were much more favorable than those found on any other oyster ground. For the 72 hauls made on this bed there was an average of 165 living oysters, with only 16 empty hinged shells. Marketable oysters, small oysters, and spat averaged 46, 56, and 63 per haul, respectively. The relative amount of cullings taken with the oysters was much larger than on other beds, there being an average of 138 shells in each haul.

Twelve hauls were made on the public oyster ground in Juniper Bay (No. 41), which is so situated as not to be exposed to storms from the southeast, and the empty hinged shells taken here were only 4½ per cent of the living oysters. The average numbers of marketable oysters, small oysters, and spat brought up in the dredge were 61, 62, and 88, respectively.

On the public ground (No. 38) near Bluff Point, where 14 hauls were made, the work showed that the number of oysters smothered by the drifting sand was equal to about 11 per cent of the living oysters.

Although it is evident from this investigation that the beds of this section have been much overworked and that they are liable to con-

siderable damage by storms, it is also apparent that the oyster grounds have increased in size many fold since Winslow made the survey of 1888. This demonstrates that much of the bottom not producing oysters in 1888 was suitable and only needed to be planted with oysters and cultch in order to become productive. The same possibilities exist at the present time, and the natural extent of the oyster grounds can be greatly increased by strewing shells and oysters judiciously.

Close and indiscriminate dredging, however, has done more damage to the Pamlico oyster grounds in the past two seasons than any storms such as those of August and October, 1899, which at worst are of rare occurrence, and the effects of which are more easily and quickly remedied than the injury done by the dredgers, of which fifty could be counted from the *Fish Hawk* on the beds of section 16 in January, 1900. For the past two or three seasons these vessels have carried to the canneries everything they have taken from the beds, and, as a result, at the end of February, 1900, it was a tedious process to fill a dredge with either oysters or shells from the beds off Shell Point or in the mouth of Swan Quarter Bay, where the oysters are of the best quality and bring the best prices. No culling whatever has been done and there has been no attempt, so far as the writer is aware, to enforce the cull law, which provides for the return to the beds of all shells and small oysters at the time they are dredged. The cullings were found on the shell piles at the canneries, and it is doubtful whether a sufficient quantity of either seed oysters or cultch is left on the beds to provide the necessary means to obtain a new stock of oysters. The entire surface of the Chesapeake beds can be removed without permanent injury, for the uncovered deeper stratum of shells affords the necessary places for the attachment of spat; but the beds of Pamlico Sound differ from the natural beds in Chesapeake Bay and the North in that they are situated on the surface of the sand and have very little depth of shells.

When well strewn with shells, with here and there an adult oyster, it is a question of but two or three years until an oyster bed may be expected to be again productive, but when swept clean of everything, like the beds in section 16, the time required for it to become restocked by natural means may be as long as was required for the original growth of the beds.

Dredging, when properly done, is most beneficial to an oyster ground. It rapidly extends the area, for on every tack the dredging schooner spills oysters and shells as she sails past the edges of the bed. Another benefit is seen in the superior quality which as a rule characterizes the oysters taken from dredging grounds, as compared with those grown on unworked or tonging beds. The reason for this is probably in the fact that a dredger clears the beds of mussels to some extent. A tonger culls closely and throws back the mussels, thus leav-



A DREDGING VESSEL AT WORK, PAMLICO SOUND.



A "DREDGER," SHOWING DREDGES IN PLACE.



ing a larger proportion of them than before. The food of oysters and mussels is the same, and there can hardly be enough in the water over the beds to supply the enormous number of both these animals that live on some of the beds in section 16.

The bottom of the beds in this section, on which oysters of good shape and condition are found, and which underlies practically all of the natural beds, is invariably one of hard sand with a thin layer of soft organic sediment covering it. The oysters found on muddy bottoms are of ill shape and are usually poor. In the Beaufort region the conditions indicated that bottoms composed of hard sand are not adapted to growing oysters, but the Pamlico natural beds produce a finer grade of oysters than do the mud bottoms of section 24. A sandy bottom, however, is liable to be shifted and torn to pieces by the action of the waves unless it is located in a sheltered place or is held together by grass roots. To this fact is probably due the character of the natural reefs of Pamlico Sound, to which reference has been made. The beds are disturbed too often to give opportunity for the accumulation of a thick layer of shells.

The following table, based on observations made during January and February, 1899, gives the average density of the water at various localities in the section, and for comparison the densities in the same localities, as reported by Winslow in 1887, are reprinted. During the months of November and December, 1900, a number of observations on the density of the water were made at station 2, and the average during that period was found to be 1.0162.

*Average densities of water in Swan Quarter Bay.*

Station.	Location	Densities.		
		1899.		1887.
		Surface.	Bottom.	
1	Near can buoy in mouth of Swan Quarter Bay .....	1.0104	1.0106	1.010
2	Near spar buoy above mouth Caffee Bay .....	1.0091	1.0098	1.010
3	Near spar buoy opposite mouth Oyster Creek .....	1.0098	1.0099	1.010
4	Near spar buoy $1\frac{1}{2}$ miles south of east end Swan Quarter Island ..	1.0094	1.0098	1.0103
5	Near can buoy 5 miles south of east end Swan Quarter Island...	1.010	1.0107	.....
6	Near can buoy $8\frac{1}{4}$ miles southeast of Great Island in Swan Quarter Narrows .....	1.0107	1.0119	1.009
7	In Swan Quarter Narrows .....	1.0091	1.0095	1.0105

The currents in section 16 vary greatly, and observations show that their direction and velocity are governed almost wholly by the wind, there being little evidence of the influence of tides. The measurements taken varied from an almost imperceptible "set" to a maximum of one-half mile per hour. During the stay of the *Fish Hawk* in the section there were very few days when there was not a constant change of water taking place over the oyster beds.

The notes taken on the food resources of this section are given on page 286 and in the table, page 290. Animals that live with the

oysters and in the water in the region of Swan Quarter were carefully collected. Those which may be considered as enemies are the "drill" (*Urosalpinx cinerea*) and the mussel (*Modiola hamatus*). The drill feeds upon mollusks, but it is not sufficiently numerous to be of noticeable damage. The mussel is extremely abundant, however, and, as mentioned above, it injures the oysters wholly by its numbers, cutting off their water and food supply.

#### WYESOCKING BAY.

Wyesocking Bay (section 10 of the Winslow survey) is noted among the North Carolina oystermen as containing some of the best oyster grounds in Pamlico Sound. The oysters are said to be the earliest to fatten as the oyster season comes on, and to continue marketable until late in the spring. This section was therefore selected as the second place for work. From February 28 to March 17, 1900, the *Fish Hawk* was stationed near Gull Shoal off the mouth of Wyesocking Bay, but, the weather being stormy, very little work was accomplished and the survey of the section was postponed. It was resumed November 16 and completed December 14, 1900.

The conditions that prevailed during February and March were almost ideal for oyster culture. Food was extremely abundant and the density of the water over the largest and most productive beds in the section was the same as that over the best oyster grounds of the Chesapeake. In December the conditions were much changed, as will be noted in the density tables below and the food table (p. 290), but are not to be considered normal at that time, being the result of the unusual drought which prevailed in North Carolina during the summer and fall of 1900.

#### Densities in Wyesocking Bay.

Date.	Station 1 (anchor- age).	Station 2, bed No. 26.	Station 3, bed No. 29.	Station 4, bed No. 27.
Winslow's survey, 1887.....		1. 0122	1. 0121	1. 0125
February and March, 1900.....	1. 0114	1. 0118	1. 0096	1. 012
December, 1900.....	1. 0179	1. 0192	1. 0186	1. 0188

NOTE.—Water taken near the bottom was used as the basis in making the table. The water at the surface would be slightly fresher.

The bottom on the offshore areas is composed of hard sand covered with a layer of mud. On the beds the mud is thick with shells and shell fragments. Inshore the substratum of the beds is often of clay, and the layer of mud is thicker than on the offshore areas. In some places at the head of the bay the bottom is a very soft, deep, organic mud—the washings from the marshes.

On perfectly calm days it was often not possible to detect currents in the water at all, but when the wind was blowing, or on days following a storm, currents with a maximum velocity of nearly half a mile

per hour were noted. The slight rise and fall of the tide is not sufficient to influence the currents perceptibly.

Winslow charted 12 productive natural oyster beds in this section, which he numbered from 26 to 37, inclusive. Such of these as could be found in 1899 and 1900 were carefully examined. Those located inshore (Nos. 29 to 37) seem to have disappeared entirely, either through the action of storms or because of overfishing. The location of some of them was indicated by the presence of scattered shells and now and then an oyster, but nothing that could be called a productive natural bed was found. The offshore beds (Nos. 26, 27, and 28) were found to have been considerably reduced in area. The oysters taken from them in December by the oystermen were small, very few measuring more than 3 inches in length. These beds are abundantly furnished with shells, to which many small oysters and spat were attached.

The area of productive beds in this section has never been large and the oystermen that have frequented them are many. None of the beds is in water having a depth of 10 feet; they are therefore not open to dredging, but are set aside for the exclusive use of tongmen. There were dredge boats on the beds, however, in addition to the numerous tongers to be seen from the deck of the *Fish Hawk* in December, and this overfishing is probably responsible for the destruction of the small inshore beds and the reduction of area of the larger offshore grounds.

Mussels, which are so abundant in section 16 and which constitute the most serious obstacle to oyster culture there, are not numerous in section 10. The oysters have no natural enemies of consequence. Winslow's opinion that almost the entire bay is suitable to oyster culture was borne out by the observations of the *Fish Hawk*. It was very evident also that the section is at present not producing one-tenth the quantity of oysters it should produce.

#### OYSTER FOOD IN NORTH CAROLINA WATERS.

The methods used in studying the oyster food in the waters of North Carolina have been described on page 254, and the results of the work are given in tables on pages 267, 272, 289-90. The objects were to determine the relative value of different localities for maintaining oysters, the constituents of the food in each locality, their sources, and whether the supply is constant in quantity and quality from season to season and from year to year.

Some who have hitherto worked on this problem have stated that minute animals, as well as plant forms, constitute a considerable part of the oyster's diet. My observations, however, have not verified this, but have shown that plants alone constitute the food of North Carolina oysters. Fragments of small crustacea and the eggs of certain animals



have sometimes been found in the stomachs of the oysters, but so sparingly that they formed no appreciable part of the food.

It is the opinion of the oystermen that much of the food of the oyster comes from fresh-water sources, and they thus account for the fact that oysters thrive best in brackish water. This also I have been unable to substantiate, having found, on the contrary, that the plant forms which compose the oyster's food are produced on the bottom of the rivers and bays in which the oyster beds are located, in the brackish water over the beds, or in the salt water carried over the beds by the tide. Plants similar to those utilized by the oysters but not identical species were found in the ooze at the surface of the bottom of fresh-water streams, ponds, and marshes in the region of the oyster beds.

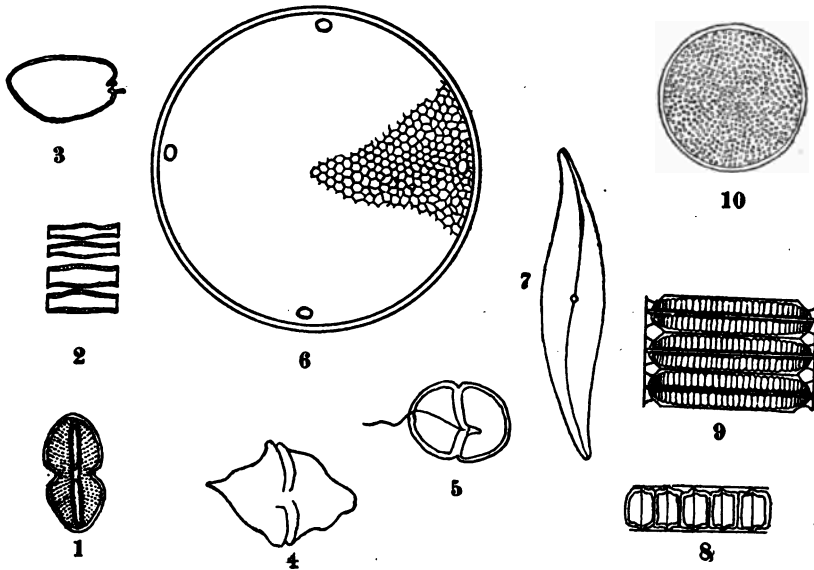
The plant forms that furnish the oyster food in North and Newport rivers are the same, though not equally abundant in the two streams. As many as 30 species of diatoms were found, from first to last, in the stomachs of the oysters, but nine-tenths of the bulk of the contents was made up of individuals of four species, figures for which are given on page 286. These species are, in the order of their abundance, *Melosira sculpta*, *Pleurosigma spencerii*, *Eupodiscus radiatus*, and *Navicula didyma*.

*Melosira sculpta* is a species of diatom the individuals of which adhere end to end, thus forming filaments, which are quite brittle, however, and seldom contain more than ten individuals, the usual number being five or six. The individuals are disk shaped and have beautifully sculptured walls (fig. 9). The filaments have no motion of their own, and are hence found chiefly on or close to the bottom, except on windy days when the water is considerably roiled. The species is equally abundant in the rivers, harbor, and the open sea, and forms a considerable part of the diet of oysters everywhere in the Beaufort region. It was not found in any locality in Pamlico Sound, except near Ocracoke Inlet, which fact, taken with the above, indicates that it is a marine form.

*Eupodiscus radiatus* (fig. 6), is the largest diatom found in Beaufort waters. The individual plants are disk-shaped and nonmotile, but, unlike those of the preceding species, are always found singly and usually above the bottom. Owing to this position above the bottom, the reef oysters usually contain a larger proportion of these plants in their stomachs than the oysters on the beds in deeper waters, and from the fact that the diatom is more common in salt than in brackish water, the oysters on the beds near the mouths of the rivers and in the harbor get a more plentiful supply than those farther up the rivers. The species was found in Pamlico Sound near Ocracoke Inlet, but not over the beds in Swan Quarter and Wysocking bays. Although the number of individuals found in the oysters' stomachs

or in a given quantity of water was much less than the number of individuals of the other important species, *Eupodiscus* nevertheless represented more real nutriment than they, as will be shown farther on.

*Pleurosigma spencerii* (fig. 7), is an S-shaped species which lives and multiplies at the surface of the mud flats of both the Beaufort and Pamlico Sound regions. It becomes especially abundant during the hot summer months and furnishes the principal part of the food of oysters in the vicinity of the flats. It is less abundant, both in the water and in the oysters' stomachs, the farther from muddy bottoms the specimens are collected, and the quantity available from



Outline drawings of the principal constituents of the food of North Carolina oysters.

- |                             |                                       |
|-----------------------------|---------------------------------------|
| 1. <i>Navicula didyma</i> . | 6. <i>Eupodiscus radiatus</i> .       |
| 2. <i>Diatoma</i> sp?       | 7. <i>Pleurosigma spencerii</i> .     |
| 3. <i>Prorocentrum</i> sp?  | 8. <i>Melosira</i> sp?                |
| 4. <i>Heterocapsa</i> sp?   | 9. <i>Melosira sculpta</i> .          |
| 5. <i>Glenodinium</i> sp?   | 10. <i>Coscinodiscus perforatus</i> . |

year to year varies considerably, as may be seen by reference to the food tables on pages 289-90. The cause of this variation is not clear. In the Beaufort region the diatom was least abundant during the very wet season of 1901 and was most plentiful during the drought of 1900, yet in Wyesocking Bay just the reverse was true.

*Navicula didyma* (fig. 1), is 8-shaped and, like the preceding species, is motile and lives at the surface of mud flats. It is easily taken up and carried about by the water, and usually forms a very appreciable part of the diet of oysters both in the Beaufort and Pamlico Sound regions.

Among the many species of diatoms found in the stomachs of Beaufort oysters, but which have not been taken into account, either because of their minuteness or their scarcity, one may be mentioned which, after *Navicula didyma*, was next in value. It is an undetermined species of *Coccinodiscus*, and was usually present in the stomachs and in the water in greater numbers than the individuals of *Eupodiscus*. It lives above the bottom, like the latter, and has the same disk form, but it is so minute that 150 individuals would be required to make a volume equal to one *Eupodiscus*.

The relative values of the four forms considered in the tables are as follows: The volume of an individual *Eupodiscus* being 100, that of a filament of *Melosira sculpta* is 33½, of a *Pleurosigma* individual 10, of a *Navicula didyma* individual 3½.

The supply of oyster food in Pamlico Sound has not been sufficiently investigated to warrant definite statements regarding it. Two sections only have been studied, section 16, containing Swan Quarter Bay, and section 10, Wysocking Bay, both on the Hyde County shore. Furthermore, the method of determining the amount of available food in the water was developed only during the latter part of the survey of the sound. The tables therefore show the food value of the water in but one section, Wysocking Bay, and that for very short periods during one spring and winter. The figures given for Swan Quarter Bay were obtained after the survey of that section had been completed, from a single examination of some oysters obtained from the Swan Quarter Narrows while the survey of Wysocking Bay was in progress. Opportunity to obtain specimens of water and oysters for further examination was not afforded. Qualitative examinations (with the microscope) had been made, however, of the contents of the stomachs of the oysters from many of the beds in section 16 and from these it was found that the food on the inshore beds, of which the beds in Swan Quarter Narrows are examples, is quite different from that on the beds in deeper water offshore, *Peridineæ* being much more abundant in the oysters from the Narrows. The food resources of section 16 also differed considerably from those of section 10, as may be noted from the table.

In section 10 the supply of food in March was very much richer than in November and December. The difference in amounts noted at these times may be the normal variation pertaining to the season of the year, but it was more probably due to the extreme drought of 1900, which caused the density of the water over the beds in the entire sound to rise much above its normal. The plants constituting the food of oysters in sections 10 and 16 were not found abundant in the sea or in the sections near the inlets, and it is probable that they thrive only in the very brackish water conditions which usually prevail along the western shores of the sound.

The bulk of the food supply in Wysocking Bay consisted of eight species of plant forms—five diatoms and three Peridineæ. Several other diatoms and Peridineæ were occasionally found in the oysters' stomachs, but not in sufficient numbers to be considered important elements of their diet.

The plant that appeared most abundantly was a beautiful disk-shaped diatom, *Coscinodiscus perforatus* (fig. 10). It lived mainly in the water above the surface of the bottom and, as is evident from the table, was not so available to the oysters as the one next referred to. It was very much more abundant in the water in March than in November and December.

An undetermined species of *Melosira* (fig. 8) was the next most important constituent of food in this section, and, with one exception, it seems to be the most constant element. The individuals of this species are much smaller than those of *Melosira sculpta*, but, like the latter, they adhere end to end, forming filaments, and are found in greatest abundance near and upon the bottom.

*Pleurosigma spencerii* and *Navicula didyma* are the only species common to the food supply of section 10 and the Beaufort region. The former had diminished in numbers in Wysocking Bay from March to November, but a slight increase had taken place in the quantity of the latter.

The fifth diatom present in abundance in both the oysters and water I have been unable to identify. It is an elongated form, the individuals of which lie side by side in small colonies, as I have shown roughly in figure 2 on page 285. Less difference was noted in the abundance of this species during March and November than for any other. It seemed to thrive as well in salt as in brackish water.

None of the Peridineæ could be specifically identified, but the genera to which they belonged were determined. The species of *Glenodinium* (fig. 5) was conjugating in March and, because of the large buoyant gelatinous capsules secreted about them, the individuals were quite evenly distributed through the water. Those not inclosed in capsules were not dependent upon the currents in the water for their distribution, but moved about actively. This species had almost completely disappeared in November. *Heterocapsa* (fig. 4) is found in greater abundance near the bottom than at higher levels or at the surface of the water, and is more abundant near the mainland and marshes than over beds offshore. It, too, had almost disappeared in November. The species of *Prorocentrum* (fig. 3), on the other hand, was very much more numerous in November than in March. Individuals were occasionally found in the oysters from the beds near the mouths of Newport and North rivers and in Jarrats Bay, which indicates that this form is adapted to water with a high density, such as prevails in

the places last named and as was found in Wysocking Bay in November, 1900.

The food supply in section 16 differed very much from that in either section 10 or the Beaufort region. The inshore beds also differed considerably in this respect from those in deeper water. On the offshore beds during January and February the oysters were living chiefly on diatoms (*Melosira* sp.?, *Coscinodiscus perforatus*, *Pleurosigma spencerii*, and *Navicula parca*), with a much smaller bulk of the same species of Peridineæ mentioned as having been found in section 10, but, as the table shows, the food on the inshore beds consisted mainly of Peridineæ, the water swarming with these plants.

While the oysters on some of the tonging grounds and on the unworked beds in deep water are frequently poor during the oystering season, it does not necessarily follow that the food supply is at fault, for on the beds just mentioned the oysters are not only very numerous and closely crowded, but each oyster is literally covered with mussels, the diet of which is the same as that of the oyster. One hundred mussels is not an unusual number to find attached to a single oyster on such beds, and since the water must pass the mouths of all these mussels before reaching the mouth of the oyster it is not surprising that there is not enough food for all.

*Food of North Carolina Oysters.*  
NEWPORT RIVER—CROSS ROCK.

Date of examination.	Density of the water.	Condition of the oysters.	Food.									
			Melostoma sculpta.		Pleurosigma spencerii.		Eupodiscus radiatus.		Navicula didyma.		Total.	
			Oyster.	Water.	Oyster.	Water.	Oyster.	Water.	Oyster.	Water.	Oyster.	Water.
Apr., 1900	1.0168	Very good	6531	1920	2964	6720	1254	960	2052	2400	12901	12000
May, 1900	1.0172	do	5628	4290	2520	5866	1092	5866	420	2400	9660	16022
May, 1901	1.004	Good	2025	840	3136	2520	216	675	131	225	5508	4280
June, 1900	1.0071	Very good	6478	3600	27298	33120	1533	1440	547	338	35364	38160
June, 1901	1.0080	Good	3874	2102	1202	1612	686	1484	547	338	6309	5486
June, 1902	1.020	Fair	3058	1670	504	1671	106	432	24	289	3692	8680
July, 1900	1.0214	do	5724	1864	9063	48416	106	432	159	482	15052	51144
July, 1901	1.0074	do	2666	2842	567	3381	196	490	87	294	3516	7007
July, 1902	1.0196	do	2915	1432	4638	27309	53	120	80	120	7686	29881
Aug., 1900	1.0208	Good	5272	1088	12804	62208	824	983	979	980	19879	65209
Aug., 1901	1.0149	Fair	4361	1470	5071	6071	195	392	152	294	7274	7227
Aug., 1902	1.0219	Good	2566	2267	12058	46985	27	358	65	480	14205	49610
Sept., 1901	1.0141	do	3615	3891	1895	4410	65	653	65	480	15640	9244
Sept., 1902	1.0143	do	1903	597	11862	23836	.....	1198	.....	.....	13765	31126

NEWPORT RIVER—EXPERIMENTAL OYSTER BED.

Apr., 1900	1.0168	No oysters on bed.	10296	2786	2876	864	2376	1008	.....	.....	15264	15648
May, 1900	1.0172	Very good	1168	1884	2016	314	168	.....	.....	.....	9106	3352
May, 1901	1.0062	Good	6908	7851	62000	21428	1303	627	585	.....	74484	30617
June, 1900	1.0179	Very good	3642	2879	511	2409	209	392	352	.....	4764	6169
June, 1901	1.0069	Fair	875	1789	875	2029	133	120	136	120	7654	4058
June, 1902	1.0205	Good	5910	2169	5846	9418	881	1395	474	10268	18546	18546
July, 1900	1.0212	Fair	3324	2646	196	3416	131	588	277	294	2090	6944
July, 1901	1.0078	Poor	1676	1312	2597	4413	.....	358	133	.....	6320	6063
July, 1902	1.0210	Fair	3599	7704	2526	2996	202	1294	505	428	6869	12412
Aug., 1900	1.0216	do	3686	2572	1960	4679	208	759	231	294	7429	8304
Aug., 1901	1.0156	do	5080	2572	1960	4679	208	759	231	294	7429	8304
Aug., 1902	1.0213	do	1193	2028	7508	22181	27	1552	27	745	8750	24209
Sept., 1901	1.0151	Good	5604	8741	1022	3972	294	478	87	120	7007	15010
Sept., 1902	1.0180	Fair	1140	418	4899	14053	27	.....	159	.....	5725	15069

• *Food of North Carolina Oysters—Continued.*

**NORTH RIVER—EXPERIMENTAL OYSTER BED.**

Date of examination.	Density of the water.	Condition of the oysters.	Food:									
			Melosira sculpta.		Pleurosigma spencerii.		Eupodiscus radiatus.		Navicula didyma.		Total.	
			Oyster.	Water.	Oyster.	Water.	Oyster.	Water.	Oyster.	Water.	Oyster.	Water.
April, 1900.	1. 0164	Good	10079	5012	1011	6264	4831	3759	7766	3758	23686	18793
May, 1900.	1. 0198	Fair	4410	4109	1821	5998	1295	1992	2683	1409	9899	13508
May, 1901.	1. 0100	Very poor	1307	1688	327	1176	623	378	1241	1060	3398	4242
June, 1900.	1. 0212	Poor	5296	1388	970	2671	968	1858	1857	387	6208	6094
June, 1901.	1. 0114	Very poor	1064	1249	152	862	174	514	611	1102	2021	3747
June, 1902.	1. 0220	.....do	1113	955	139	1436	120	58	785	1580	2869	3694
July, 1900.	1. 0137	Poor	844	1728	216	1490	56	140	1758	478	1789	2369
July, 1901.	1. 0111	Very poor	984	1724	195	1490	56	140	1758	478	1789	2369
July, 1902.	1. 0223	Very poor	9915	2624	97	1312	159	239	239	389	1788	2369
Aug., 1900.	1. 0158	Fair	2156	1764	262	1748	245	808	621	294	4015	4593
Aug., 1901.	1. 0154	Fair	1948	1628	1083	3748	245	808	621	4015	6904	8594
Aug., 1902.	1. 0230	Very poor	1742	1291	818	3459	159	130	289	2458	4810	6109
Sept., 1901.	1. 0168	Fair	5586	3048	2949	4233	457	500	544	9536	8769	11573
Sept., 1902.	1. 0211	Poor	2121	2505	6569	15990	80	.....	523	88	9299	18573

**PAMLICO SOUND—WYESSOCKING BAY.**

Date of examination.	Density of the water.	Condition of the oysters.	Food.															
			Melosira sp.—?		Pleurogigma spencerii.		Cocconeidiscus perforatus.		Navicula didyma.		(?)		Proocentrum sp.—?		Heterocapsa sp.—?		Glencodinium sp.—?	
			Oyster.	Water.	Oyster.	Water.	Oyster.	Water.	Oyster.	Water.	Oyster.	Water.	Oyster.	Water.	Oyster.	Water.	Oyster.	Water.
Mar., 1900.....	1.011	Very good.....	4343	1029	2635	9187	6565	25392	14	114	1946	2572	144	2590	1423	1708	5722	
Dec., 1900.....	1.018	Fair .....	3676	2011	483	742	8463	5583	159	141	1899	2364	2123	1766				

**PAMLICO SOUND—SWAN QUARTER NARROWS.**

[illegible]

## RATE OF FEEDING.

Some experiments were made during the summers of 1900 and 1902, in order to ascertain the rapidity with which a Newport River oyster is able to collect the amount of food usually found in its stomach, and the methods and results of these experiments are given in the text and tables following.

A number of oysters were tonged from one of the Newport River natural oyster beds, and individuals of about equal size (about  $3\frac{1}{2}$  inches in length) were selected for the experiments. Three of them were immediately opened and their stomach contents removed and preserved. The others were taken to the laboratory, scrubbed clean, and put to fast for three days, in order to rid them, without injury, of the food already in their stomachs. Twice each day they were put into a tub filled with filtered sea water, so they might throw out any refuse matter which had collected and be kept in a healthy condition. It had previously been noted that digestion is not carried on normally while the animals are out of the water, and the object of these baths was mainly to stimulate the normal process of digestion and to rid the stomachs of diatoms as quickly as possible. On the fourth day three of the oysters were opened and the stomach contents then remaining were removed. This amount was made the basis for the calculations of the rate of feeding. The remaining oysters were taken back to their home feeding ground and placed in the water near a stake. At convenient intervals they were taken up (three each time), opened, and the contents of their stomachs removed. The tables show the dates when the experiments were made and the amount of food found at each examination of the stomach contents. A table is also given showing the averages calculated from the results of all the experiments. From these figures it appears that each oyster collected 385 diatoms during the first hour, 550 during the second, 1,406 during the third, and 4,301 during the fourth. This increasing rate of feeding is probably to be explained as due to gradual recovery on the part of the oysters from the shock of their unusual treatment in the laboratory. The rate at which feeding took place during the fourth hour is probably much nearer the rate at which it occurs with oysters living undisturbed on the beds.

The work on the food resources of Newport River shows the average number of diatoms per liter (or about a quart) available to the oysters on the natural beds during the summers of 1900, 1901, and 1902 to be 23,432, and that the oysters of salable size examined during this time contained, on an average, 11,453 diatoms. If the usual rate of feeding under natural conditions is near the figures obtained from the above experiments, 4,301 diatoms per hour, then three hours is ample feeding time for an oyster; and taking 23,432 as the average amount



of food contained in each liter of the water over the natural oyster grounds, it follows that in collecting its daily meal (11,453 diatoms) an oyster must filter altogether about 500 c. c., or 16 ounces, of water, and that about 167 c. c., or  $5\frac{1}{2}$  ounces, are filtered per hour. The length of the feeding time in any locality very probably depends upon the richness of the supply of food in the water, the time of feeding becoming longer as the food supply diminishes in quantity. Not until the supply of food falls below an amount one-eighth of that found in Newport River would it fail to support oysters. The "coon" oysters on the tops of the high reefs, although exposed to the air for several hours each day, are in no danger of starvation so long as they are covered by the tide for a few hours each time, and so long as the food supply retains its present richness.

*Results of experiments to determine rate of feeding.*

Date.	Time of examination.	Stomach contents.				Total.
		Melosira sculpta.	Pleurosigma spencerii.	Eupodiscus radiatus.	Navicula didyma.	
1900.						
July 31	When taken from bed .....	3,318	5,846	816	474	9,954
Aug. 4	After fasting 4 days .....	198	79			277
Do...	After feeding 2 hours .....	302	403	101		806
Do...	After feeding $3\frac{1}{2}$ hours .....	1,512	532	208	108	2,360
Aug. 6	When taken from bed .....	3,193	4,372	326	615	8,506
Aug. 9	After fasting 3 days .....	675	75			750
Do...	After feeding 2 hours .....	990	180	90		1,260
Do...	After feeding 4 hours .....	1,820	280	560	140	2,800
1902.						
Aug. 19	When taken from bed .....	636	3,551	53		4,240
Aug. 22	After fasting 3 days .....		53			53
Do...	After feeding 1 hour .....	53	987			1,040
Do...	After feeding 2 hours .....	106	530	53	53	742
Do...	After feeding 3 hours .....	265	2,809			3,074
Do...	After feeding 4 hours .....	689	10,494		53	11,236
Sept. 1	When taken from bed .....	1,216	5,300	53		6,569
Sept. 4	After fasting 3 days .....	159	265			424
Do...	After feeding 1 hour .....	121	862			483
Do...	After feeding 2 hours .....	860	1,982		90	2,432

*Average calculated from the above.*

Condition of oysters.	Stomach contents.				Total.
	Melosira sculpta.	Pleurosigma spencerii.	Eupodiscus radiatus.	Navicula didyma.	
When taken from bed .....	2,091	4,767	187	272	7,317
After fasting .....	258	118			376
After feeding 1 hour .....	87	674			761
After feeding 2 hours .....	440	774	61	36	1,311
After feeding 3 hours .....	888	1,671	104	64	2,717
After feeding 4 hours .....	1,264	5,387	280	97	7,018

## CONCLUSIONS BASED UPON THE WORK OF THE SURVEY.

Productive natural oyster beds in Newport and North rivers are confined to the upper waters, and have been materially reduced in area since 1887, the reduction caused by overfishing to supply the oyster canneries at Beaufort. In Pamlico Sound the decrease in productiveness of the natural grounds since that date is still more marked, many of the then extensive beds being almost entirely depleted, and the fact that this region continues season after season to yield a considerable quantity of oysters should not lead to the supposition that the supply is inexhaustible. The survey of sections 10 and 16 showed that the oystermen have discovered many new grounds to which they could turn when the older ones ceased to be productive, but the number of unknown grounds is not unlimited, and in the near future new beds will no longer be discoverable. Now is the time to apply the remedy, and in order to check the destruction of the natural beds in Pamlico Sound either a cull law should be enforced or shells from the canneries and raw houses should be returned to the beds annually during the months of May and June, carefully and evenly scattered over the depleted areas, about 2,000 bushels per acre.

The physical and biological conditions existing in Newport and North rivers are very favorable to the growth of young oysters, but are not so well suited to the production of large marketable stock. The supply of available oyster food is abundant and has been fairly constant during three seasons. The currents in the water are such as to insure a good circulation of pure water over the beds and a constant supply of food to each oyster. The amount of lime salts in the water is also adequate to their needs. On the other hand, the density is usually too high and the bottom outside the natural beds is too soft.

The conditions in Pamlico Sound are very different from those in section 24, and, on the whole, are better adapted to the production of oysters. There are extensive areas where the density of the water is perfectly suited to the needs of the animal. The currents are a trifle too sluggish, and there are times during very calm weather when the circulation over the beds is not as rapid as is desirable, but food is very abundant and the bottom has the necessary firmness, though it is mainly composed of sand, and in exposed areas is likely to be shifted during high winds.

Oyster planting has been unsuccessful both in section 24 and in Pamlico Sound. The failures, however, have not been due to insurmountable difficulties existing in the various localities, but to lack of experience on the part of the planters or to a belief that an experience in planting oysters in the North is an adequate preparation for planting in an entirely different section of the country where the conditions are very different. Each oyster-producing section has an oyster question of its own entirely separate from that of other localities, and a

failure to recognize this fact is likely to lead to failure in any attempt to grow oysters. There is no one oyster question, but there are many oyster questions.

In order to encourage an industry in oyster planting in North Carolina, certain areas in localities which are known to be or to have been productive of oysters should be set aside for the use of planters, and provision should be made to guarantee their rights effectively.

#### OYSTER-PLANTING EXPERIMENTS IN NEWPORT AND NORTH RIVERS.

The "oyster gardens" of the North Carolina coast date back to the year 1840, but, as before stated, they were used mainly as places for bedding oysters for family use, no attempt being made to carry on an industry for commercial purposes. The years immediately preceding and following the oyster survey by Winslow in 1886-1888 and the completion of the railroad from Wilmington to Jacksonville in 1890 witnessed the greatest enthusiasm in oyster planting in North Carolina. Hundreds of acres of bottom were taken up during this period and thousands of bushels of oysters were planted. In very few cases, however, were the results such as to encourage the continuation of the operations already begun or the beginning of new ones. A revival of the interest took place in Carteret County in 1896 as the result of the success of some of the plants made in North River and Jarrats Bay in 1891, and many entries of ground were again made and considerable planting done, but in 1899 there was not a single oyster bed anywhere in North Carolina, so far as I have been able to ascertain, which was being cultivated or which was yielding or had yielded its owner an income in anyway commensurate with the labor and expense put upon it. It seemed that the industry had been given a fair trial, had proved a failure, and was now a thing of the past, so far as North Carolina was concerned.

The failure is much more apparent than real, however, from a statistical point of view, for of the very large number of entries of ground made for the avowed purpose of oyster planting comparatively few were ever so used. In most cases the ground was entered as a speculation, the purpose of the owner being to hold it until a profitable industry in oyster planting should be developed. The improvements put upon such beds consisted usually in nothing more than setting boundary stakes. The existing adverse opinion of the waters of North Carolina as a field for oyster culture therefore rests upon a very questionable foundation, since in the sum total of complete failures such beds as those just mentioned form a very considerable part.

To many of the public-spirited men of the State the outcome of the enterprise was very disappointing. There seemed to them no reason why the waters of North Carolina should not be as well adapted to

oyster culture as those of the North Atlantic States, and not until the question had been thoroughly investigated were they willing to allow the subject to be dropped and the effort given up. It was therefore decided, in addition to a general study of the conditions prevailing on both natural and planted beds, to begin some experiments in Beaufort waters, various methods of preparing the bottom to be tried before planting the oysters. Accordingly, when the steamer *Fish Hawk* left Pamlico Sound in March, 1900, the writer was directed to go to Beaufort, get together an equipment suitable for the work of planting shells and oysters, and begin operations. The outfit secured was such as is owned by the local oystermen and fishermen—namely, a small one-mast sharpie, skiff, oyster tongs, shovels, buckets, and an ax. One laborer was hired to assist in the work.

*Recent experiments.*—In selecting grounds for the planting experiments care was taken that they should include no natural oyster beds. Two beds were surveyed and marked with stakes before the *Fish Hawk* left the Beaufort region—one in Newport River, containing 5 acres, the other in North River, containing 10. On the Newport bed, situated just above the mouth of Harlow Creek (see map), the bottom has all the conditions to be found on the entire river bottoms, from hard white sand to very soft deep mud. The depth of water over it varies, at low tide, from 1½ to 4 feet. The currents are tidal in origin and at this point in the river they sometimes attain a velocity of nearly three-fourths of a mile per hour. The North River experimental bed is situated off the mouth of Roberts Bay and on the east joins the oyster garden belonging to Mr. M. E. Piver. The bottom is composed wholly of deep, soft mud. At low tide the water over it is from 3½ to 5 feet in depth. As in Newport, the currents in North River are mainly tidal, and for some time before low or high water a velocity of one-third of a mile per hour is reached in the vicinity of the bed. In order that the experiments in both rivers should be conducted on bottoms of different kinds, Mr. Elias Piver very kindly allowed us to make use of the hard sandy part of his garden, on which one planting was made.

As far as was possible the work in these rivers was carried on in the same way, each planting in the one being duplicated in the other. It was the intention to take the temperature of the water as regularly as the density, but this was neglected so often, the thermometer being in use elsewhere, that the records are too incomplete to be of much value. During the months of June, July, August, and September, when low water occurred during the middle part of the day, the temperature over the beds often rose as high as 90° F., but the usual summer temperature is about 80°. During the winter months ice often forms over the beds.

The climatic conditions which prevailed during the three years cov-

ered by the experiments were fortunately very different. The first season was very dry, especially the latter part. From April to September the average density of the water over the Newport bed was 1.0189; over the North River bed, 1.0202. The second season was very wet, the effect of the fresh water being noticeable even to Beaufort Inlet. From May until September the average density was 1.0103 and 1.0129 in Newport and North rivers, respectively. During the season of 1902, from June until September, the average density over the Newport bed was 1.0202; over the North River bed it was 1.0224. From the last figures it would appear that a greater drought prevailed in the vicinity of Beaufort in 1902 than in 1900, but this is explained by the fact that the work in 1900 covered the months of April and May, when the effects of the spring rains were yet noticeable, while in 1902 the work began with June, when the fresh water which had fallen in the spring had become well drained off. The density for each month is given in the food tables on pages 289-90.

It having been ascertained that Newport and North River oysters are in spawning condition as early as March and continue to spawn until late in December (see page 275), it was decided that plantings should be made in the spring, summer, and fall, in the hope thus to find the most favorable time for exposing spat collectors. Expensive and time-consuming methods of planting were avoided as wholly impracticable for the North Carolina oyster industry. In Europe, where large single oysters often sell for 5 cents each, it is possible to construct expensive claires for fattening the oysters, to expose tiles coated with a layer of lime for collecting spat, to take up the exposed tiles and painstakingly scale off the small oysters, to plant these in baskets constructed especially for this purpose, and to variously elaborate the methods of culture; but in North Carolina, where the price is frequently as low as 15 cents per bushel and seldom reaches a price higher than 45 cents per bushel, such refined processes are out of the question.

The liberation of artificially fertilized oyster eggs in the water has been suggested as a method of increasing the number of oyster fry in certain localities, but after repeated trials it has not proved successful, and no attempt was made to follow it here. In North Carolina the operation is expensive, not only from a practical dollars-and-cents standpoint, but from the biological point of view as well. Fully one-third of the eggs that can be taken at any one time from a spawning female oyster are unripe, are therefore incapable of fertilization, and are lost. Moreover, in taking the eggs and sperms the adults are sacrificed; and practice has shown that the young oysters that develop from eggs confined in hatching dishes or troughs all die before they attain the settling or attaching stage, probably from lack of proper food. Young attached oysters have never been procured from eggs

so kept. Doubtless if, instead of keeping the eggs in hatching dishes for any considerable time after they have been fertilized, they should be deposited in the water near the place where it is desired to establish a bed, they would pass through their development normally, provided they did not encounter adverse climatic conditions, such as a cold rain. This has been found to be fatal to free-swimming oyster fry. In order that the fry resulting from the deposited eggs shall be secured in the desired localities, it is necessary that the tides and river currents be such that the free-swimming oysters shall be carried over the exposed cultch at just the time when they are ready to settle and become attached, and as it is not possible to calculate when the attaching stage will be reached, the chances are that none of any one lot will fix themselves to cultch exposed to receive them.

If, on the other hand, the oysters are allowed to remain in the water and spawn normally, the least amount of loss of spawn takes place, and there is the greatest possible chance of securing a proportion of the resulting young oysters. So many spawning oysters live together on a bed that the chances of a failure of ripe eggs to meet with sperms are few. The spawning of an individual oyster probably covers a considerable period of time (six to ten weeks), the reproductive elements being given out a few at a time as they mature. In this way none are lost, but every egg has a chance to develop, and during the breeding season there is probably not a time when there is not present in the water in every locality in the vicinity of oyster beds a considerable number of fry in all stages of development. Thus a bed may be established at any desired point by simply exposing the proper cultch in the proper way.

Spawning oysters may be deposited in localities where natural beds are wanting, but in North Carolina the reefs furnish an abundant supply of spawn. My experiments have shown that there is no difficulty in securing a good set of spat on planted shells; in fact, the difficulties seem to lie in the other direction—in limiting the number which may be secured. The work undertaken, therefore, aimed at a simple method of utilizing the supply of fry already present in the water.

Since oyster shells are available in immense quantities at very little cost at many points on the North Carolina coast, they were used in the experiments not only as spat collectors but for hardening the bottoms of such beds as were to receive the seed oysters. Many of the Beaufort oystermen who professed to have had experience in shell planting advised against the use of steamed shells, giving as their reason that young oysters will not attach to shells which have passed through the steaming process. After exposing both raw opened and steamed shells to the same conditions, however, I have not found that oyster spat have any preference.

In addition to shells, bundles of pine brush were tried as spat col-

lectors, but in this case without success. Had the experiments with the brush been repeated with slight modifications, however, more favorable results might have been obtained, for Winslow records cases in which oysters in great numbers attached to and grew upon brush thrown into the water, and in parts of Europe this method of collecting spat is extensively used.

Since the object of the experiments in oyster planting was not to produce oysters for commercial purposes, but to demonstrate that they may be grown on muddy bottoms and to develop methods by which such planting can be done successfully, no large beds were made, but numerous small areas were planted and various methods employed. The results obtained from a small planting are just as valuable for the purpose in hand as if they were obtained from plantings covering acres.

Before an area was planted with shells or oysters it was marked off with stakes and the bottom examined either with a sounding rod or by wading about over it. The sharp in which the shells and oysters were brought to the beds was then anchored over the area to be planted, and held in position by poles thrust into the bottom, one on either side. The planting was done from the stern either by throwing the shells or oysters broadcast from the deck or, when the shells were planted in rows, by standing in the water and receiving the shells in buckets, to dump them along a line stretched between stakes.

The shells and oysters on each of the areas were carefully examined at intervals of about six months and the results of each examination tabulated. In examining for spat and larger oysters, the following methods were used: A quantity of shells was tonged from different parts of the area, and one bucketful was taken to the laboratory for examination. These were chosen at random—that is, without reference to whether they contained spat or not, it being desired that they represent as well as possible the condition of the bed. One hundred of these shells were carefully gone over in the laboratory, and the numbers of living and dead oysters noted. The living oysters were divided into five classes: (1) Spat (meaning by this term a young oyster less than one-half inch in length); (2) oysters between one-half and 1 inch in length; (3) oysters between 1 and 2 inches long; (4) oysters between 2 and 3 inches long, and (5) oysters more than 3 inches long. When it was possible to tell the cause of death, this was noted. The number of oysters attached to the inside of the shells was kept separate from the number attached to the outer surface.

The method of ascertaining the results of planting seed oysters was to tong 100 from the bed, noting how many of this number were still living, their general condition, and the amount of growth that had taken place. During the first two seasons it was comparatively easy to distinguish the shells of planted oysters that had died from the

planted shells, but not so easy during the third. Neither was it possible during the third season to distinguish the living seed oysters from the oysters grown on the beds.

The location of the experimental oyster beds is shown on the large charts of Newport and North rivers, and the location of each of the planted areas is given on the smaller charts of the experimental beds (pages 300-301). A condensed history of each of the 31 planted areas, from the date of planting to the end of the third season, is given in a table on pages 306-309. To write a detailed account of each planting in addition to this table would be to multiply words uselessly, since in many cases the methods used and the results obtained were practically the same. A few detailed descriptions of certain typical areas, however, will be necessary to give an idea of the work done and its results.

#### DETAILED ACCOUNTS OF CERTAIN PLANTING OPERATIONS.

*Area No. 1.*—The first planting was made April 26, 1900, with 41 bushels of shells arranged in five rows across the current. This 570 square feet of stiff deep mud, into which an oar can be thrust to a depth of 15 inches, is covered at low tide with  $3\frac{1}{2}$  feet of water. During the first summer an immense number of spat attached to the shells, many of which on the 6th of August measured nearly two inches in length. The number dead or killed during the first season was also large, being about two-fifths of the total number that attached to the shells. Of those found dead on August 6, about three-fifths were smothered by mud and the remainder were killed by "drills" (*Urosalpinx cinerea*), as was shown by the small round hole in the shells. The number of living oysters found on June 3, 1901, was a little less than half the number present at the time of the previous examination. Very few were larger than those found on August 6, so that either little growth had taken place or the first catch had practically all died and a new lot had become attached. During June and July, a rapid growth took place and an enormous number of additional spat were caught; but toward the end of July and the first of August every oyster died. On August 18, when the regular examination was made, 640 dead oysters were counted on 100 shells, many of them with the hinge of their shells intact. The planted shells had settled quite deep into the mud, and this may have been a partial cause of death; but from the fact that all died at about the same time, and that during July the parasitic worm (*Bucephalus cuculus*) already referred to had infested them in great numbers, I am inclined to believe that the parasite is accountable for much of the loss. No spat attached to the shells after this time; at least, none was found on those examined September 12, 1902.

*Area No. 2.*—This planting was made on the same day as No. 1, but in this case the bottom was composed of hard white sand, covered by





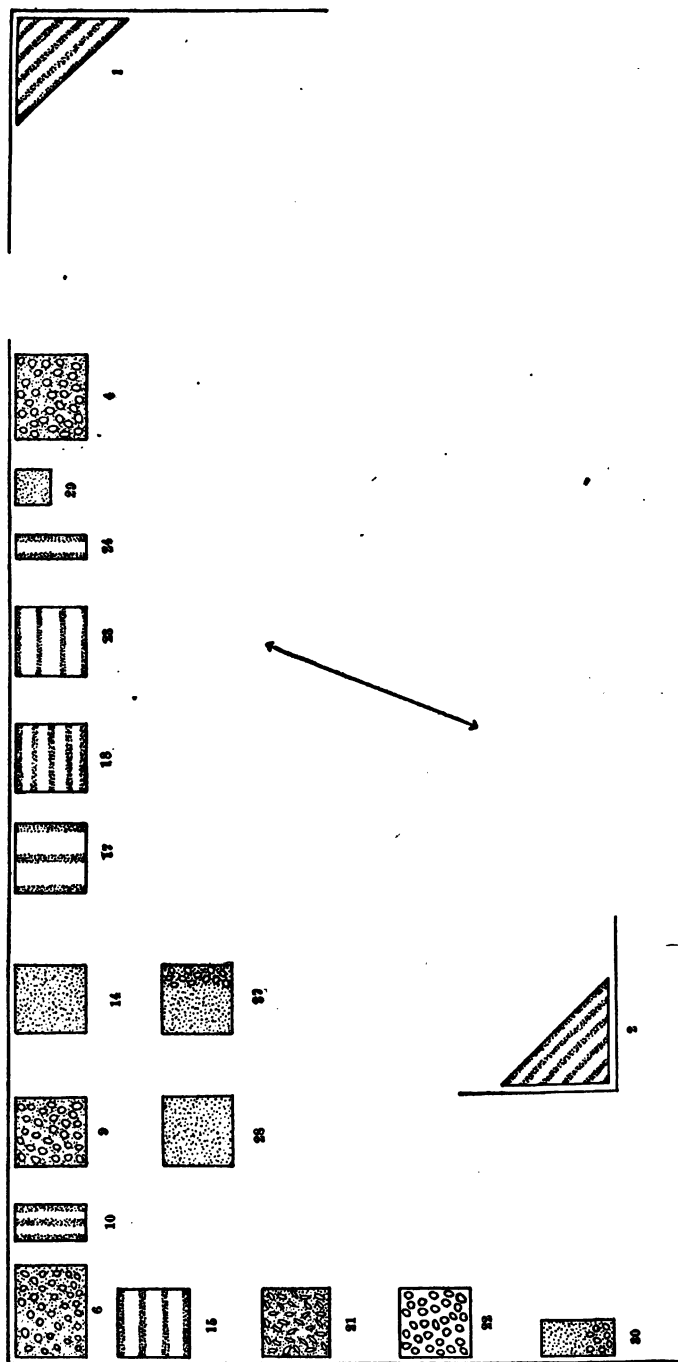


Chart of experimental oyster bed in Newport River, showing the planted areas, method of planting, etc.

about  $1\frac{1}{2}$  feet of water. Forty bushels of shells were planted in five rows across the current. During the first summer a considerable quantity of spat became attached to the shells, but soon died, owing probably to the presence of sand grains inside their shells. In rough weather the sand shifted readily, and by the end of the second summer the planted shells were all covered.

*Area No. 3.*—The third planting was made in North River on April 27, 1900, on the southeast corner of Mr. Piver's oyster "garden," which, at this end, is composed of hard white sand. The depth of the water is about 4 feet at low tide. Seventy bushels of shells were planted in four rows across the current on an area covering 750 square feet. This bed has a history similar to that of No. 2, considerable quantities of spat being caught during the first season, but killed by the sand, which entirely covered the planted shells before the end of August, 1901.

*Area No. 4.*—The ground selected for this planting, which was made May 5, 1900, was in Newport River on deep, sticky mud, covering an area of 500 square feet. Sixty-three bushels of shells were scattered over it as evenly as possible, making a layer  $2\frac{1}{2}$  shells in thickness. To this were added on May 16, 1900, 18 bushels of the best oysters that could be gathered at low tide from the edges of the reefs in Core Creek. This stock was composed of oysters of fairly good shape, but varying from  $2\frac{1}{2}$  to 4 inches in length. They were planted on the same day they were gathered, in an even layer over the shells, the average number to each square foot being about 18. These oysters have had the best history of any that were planted so far as the number that lived is concerned, as will be seen by reference to the table on page 306. They made little growth, however, the edges of their shells becoming thick and blunt.

*Area No. 5.*—Planting was begun on this area May 8, 1900, by broadcasting it with 70 bushels of shells, and was continued May 11, 1900, by adding 18 bushels of seed oysters. The location is in the southwest corner of the North River bed and contains 400 square feet of soft mud, into which it is possible to thrust an oar to a depth of 3 feet. The depth of the water varies from  $3\frac{1}{2}$  to 6 feet. The shells were scattered over the bottom, giving it a hard surface  $3\frac{1}{2}$  shells in thickness. The seed oysters were "coons" picked up from the reefs at Howlands Point, and many of them were in small clusters. They lived well during the first season, but many died during the following winter and spring, 20 per cent only being left on May 30, 1901. On September 9, 1902, none were found, although a considerable number of the spat grown on the bed were doing well. Little or no improvement in the shape of the seed oysters was noted. The transplanted oysters were taken from a locality where the water is usually very salt to one in which the density is much lower.

*Area No. 6.*—On May 14, 1900, the sixth planting was made in Newport River, on 500 square feet of sticky mud, in from 3 to 5 feet of water. Eighty bushels of shells were evenly distributed, giving the bottom a coat  $3\frac{1}{2}$  shells in thickness. On the following day 18 bushels of the best single oysters that could be gathered from the edges of the Cross Rock beds were scattered upon the shells. During the first season very little growth took place among the seed oysters, but in 1901 they grew rapidly, though not so rapidly as the oysters that attached to the planted shells, for it was not always possible during the third year to distinguish the oysters that had been planted from those grown on the bed. During the summer of 1900 the planted shells became the home of an abundance of animals of different kinds, including ascidians, anemones, leptogordias, sponges, and bryozoa, but these were all killed by the fresh water in 1901. Since then the beds have been comparatively free from all animals, excepting barnacles and a few species of snail which are always common on the oyster beds in this locality.

Although nearly half of the planted oysters were dead on August 17, 1900, and the number of spat that attached to the shells was never very great, the bed was well stocked in 1902 with large oysters of fairly good shape, many of which were used in the Beaufort laboratory.

*Area No. 9.*—This area of soft mud in Newport River, containing 400 square feet, was planted May 31, 1900, with 50 bushels of shells, distributed over the surface as evenly as possible in a layer  $2\frac{1}{2}$  shells in thickness. On June 12, 1900, there were added 15 bushels of good oysters tonged from the Cross Rock beds. These oysters, everything considered, have had the best history of all the plants made. The per cent living at the end of the second season was not quite so high as in two other cases, but a more rapid growth took place. On many of the beds the planted oysters became blunt and thick-shelled, but the shells of these were thin and showed rapid growth. The spat that attached to the planted shells grew rapidly also, and the oysters were well shaped. During the third season they had attained the size of the planted oysters, from which they could not be distinguished. While no careful examination of the beds was made in 1903, this one was frequently visited, and bushel after bushel of fine oysters removed from it.

*Area No. 13.*—The description of this area is given here for better comparison with the one just described. It includes 400 square feet of very soft muddy bottom in North River, which on June 21, 1900, was evenly covered with a layer of shells 3 shells in thickness, 63 bushels being planted. Four days later 15 bushels of finely shaped oysters, tonged from the Cross Rock beds in Newport River, were distributed over the shells. It will be noted that the stock for this planting was the same as that planted on area No. 9, in Newport River,

and that the oysters were planted at about the same time and upon similar bottoms. The results of the two plants, however, are very different. Ten per cent only of those planted in North River were living at the end of the second season, little or no growth having taken place, while 68 per cent of those planted in Newport River were growing nicely when the examination was made in September, 1902. The difference in the food supply on the two beds was not great enough to account for the difference in result, as will be seen by reference to the tables on pages 289-90. The principal difference in the conditions was that in the first instance the oysters were transplanted to a locality in which the density is not usually much higher than that over their native rock, while in the second a considerable change was experienced in this respect, the North River experimental bed usually being covered with water having a much higher density than the Cross Rock beds.

*Area No. 12.*—The twelfth planting was made in North River June 13, 1900, with 60 bushels of shells in two rows parallel to the currents. The area is small, covering but 200 square feet. As was usual with shells planted in rows, either parallel or at right angles to the flow of the currents, large numbers of spat became attached and the oysters showed rapid growth, but as they grew larger there was a tendency to become long and narrow. The spat becomes attached principally to the shells at the tops of the ridges, as these offer the cleanest surfaces and the most favorable feeding conditions. Those on the sides of the ridges and at the bottom soon become coated with sediment. The conditions on the tops of the ridges are in reality too well suited to the needs of the oyster fry; too many spat usually become attached, so that as they increase in size they interfere with each other, becoming "coony" as the result. This method of planting might be used to advantage in localities where oyster fry are scarce or in cases in which the shells are to be transplanted not later than one year from the time when they were first exposed.

*Area No. 22.*—This area in Newport River was the last planted in 1900. No shells were put out, but on July 20 10 bushels of small but nicely shaped oysters, gathered at low tide from Turtle Rock, were planted on the unprepared sticky bottom. The area covered contained 400 square feet, but the bulk of the oysters were placed on the eastern half. A rapid growth took place from the beginning, and, contrary to what was expected, very few of the oysters died. At the end of the third season 71 per cent were living. Very few spat attached to the shells of the oysters. The mud upon which the plant was made contained considerable sand and was quite firm compared with that found on the west side of the bed, so that the oysters did not sink below the surface, although they became covered with a thin coat of sediment.

It will be noted, by reference to the table, that the most favorable results in planting seed oysters, the rate of mortality being considered,

were obtained from this area and area No. 4. The fact that the seed oysters for both of these plantings were brought from localities where the conditions surrounding them were very nearly those on the bed to which they were transplanted should also not escape attention, for to this is probably due a considerable part of the success. The beds in Core Creek, from which the seed for area No. 4 were taken, are surrounded by conditions similar to those on the Newport experimental bed, and Turtle Rock is but a few hundred yards above area No. 22. In no case did the oysters thrive when transplanted from beds located in places where the water differed considerably in its density from that on the experimental beds, and the death rate among the plants increased directly with the increase in this difference. The age of the plants, too, probably has much to do with their ability to adapt themselves to new and different conditions, young seed adjusting itself more readily than old.

*Area No. 14.*—This area, in Newport River, should receive special attention, since it is one on which no seed oysters were planted, but from which fine marketable oysters were taken during September, 1902. It contains 400 square feet of soft muddy bottom, and was planted with 70 bushels of shells June 30, 1900. If evenly distributed, the layer covering it would be  $3\frac{1}{2}$  shells in thickness. At the last examination, made September 12, 1902, there were seventeen oysters more than 3 inches in length to each hundred of the surface shells. If the spat from which these oysters grew became attached on the date when the shells were planted, their age would have been 2 years, 2 months, and 12 days.

Detailed record of planting experiments in Newport and North rivers.

Num- ber of exper- iment.	Location of planted area.	Size of bed.	Date of planting.	Kind of bottom.	Method of planting.	Date of examination.	Oysters less than 1 inch in length attached to—				Oysters be- tween 1 and 2 inches in length at- tached to—				Oysters be- tween 2 and 3 inches in length at- tached to—				Total number of living oys- ters attached to 100 plant- ed shells.		Total number of dead oys- ters attached to 100 plant- ed shells.	
							Concave surface.	Convex surface.	Concave surface.	Convex surface.	Concave surface.	Convex surface.	Concave surface.	Convex surface.	Concave surface.	Convex surface.	Concave surface.	Convex surface.				
1	Newport River.	Sq. ft. 570	Apr. 26, 1900.	Mud.....	41 bushels shells planted in 5 rows placed ob- liquely to currents.	{ Aug. 6, 1900 June 3, 1901 Aug. 16, 1901 Sept. 12, 1902	54 8 8	45 8 8	93 41 41	54 47 20	69 20 24	40 5 3	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	283 108 640	255 156 20	..... ..... .....	..... ..... .....
2	do	570	do	Hard sand.	40 bushels shells planted in 5 rows placed ob- liquely to currents.	{ Aug. 8, 1901 June 8, 1901 Aug. 18, 1901 Sept. 17, 1902	11 5 5	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	18 184	..... ..... .....	..... ..... .....	..... ..... .....
3	North River...	750	Apr. 27, 1900.	do	70 bushels shells planted in 4 rows placed across the currents.	{ Aug. 18, 1900 May 30, 1901 Aug. 9, 1901 Sept. 15, 1902	35 8 8	8 5 5	5 6 6	5 6 12	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	57 72	..... ..... .....	..... ..... .....	..... ..... .....
4	Newport River.	500	May 5, 1900.	Mud.....	63 bushels shells evenly scattered.	{ Aug. 16, 1900 June 8, 1901 Aug. 6, 1901 Sept. 11, 1902	8 8 16	..... ..... .....	2 5 22	..... ..... .....	3 3 6	1 11 11	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	14 15 61	42 14 (?)	..... ..... .....	..... ..... .....
5	North River...	400	May 8, 1900.	Mud.....	18 bushels oysters from Core Creek reefs evenly scattered.	{ Aug. 6, 1901 Aug. 11, 1902 Sept. 11, 1902 Aug. 18, 1900 Aug. 9, 1901 Aug. 8, 1902	100 100 100 15 15 1	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	36 189 (?)	36 189 (?)	..... ..... .....	..... ..... .....
6	Newport River.	500	May 14, 1900.	Mud.....	80 bushels shells evenly scattered.	{ Aug. 18, 1900 May 30, 1901 Aug. 9, 1901 Sept. 12, 1902 Aug. 17, 1900 Aug. 11, 1902	91 20 59 2 83 2	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	42 177 (?)	42 177 (?)	..... ..... .....	..... ..... .....
			May 15, 1900.	Shells.....	18 bushels oysters from Cross Rock evenly scat- tered.	{ Aug. 16, 1900 Aug. 17, 1901 Sept. 11, 1902	91 59 59	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	62 37	62 37	..... ..... .....	..... ..... .....

7	North River....	500	May 20, 1900.	Mud.....	72 bushels shells evenly scattered.	Aug. 18, 1900 June 6, 1901 Aug. 9, 1901 Sept. 9, 1902	2 12 88 8	9 65 12 8	9 6 2 9	8 2 4 7	1 1 5 6	14 28 178 96 10 2 85 151 85	7 4 (?) 27 2 9 (?) 44
8	do.....	400	May 25, 1900. May 30, 1900.	do..... Shells.....	70 bushels shells evenly scattered. 16 bushels oysters from Goose Creek Bay evenly scattered.	Aug. 18, 1901 June 12, 1901 Aug. 9, 1901 Sept. 9, 1902	3 8 15 38	4 14 8 48	4 8 2 5	8 8 14 22	34 2 4 1	151 (?) 85	9 (?) 44
9	Newport River.	400	May 31, 1900. June 12, 1900.	Mud..... Shells.....	50 bushels shells evenly scattered. 15 bushels oysters from Cross Rock evenly scattered.	Aug. 22, 1900 Aug. 17, 1901 Sept. 11, 1902 Aug. 27, 1900	6 2 16 22	1 2 8 5	1 4 3 2	2 8 11 13	6 2 6 2	17 7 35 66	20 4 (?) 27
10	do.....	200	May 31, 1900.	Mud.....	30 bushels shells planted in 3 rows parallel to the currents.	Aug. 17, 1901 Sept. 12, 1902 Aug. 18, 1900 June 6, 1901 Aug. 9, 1901	22 11 30 17	4 9 12 12	4 7 8 1	7 8 1 3	0 5 3 2	102 81 91 94 161 203 41 530 139 241 141 101 115 38	28 (?) 35 21 26 (?) 39 52 40 (?) 38 52 25 (?) 50
11	North River....	240	June 5, 1900.	do.....	70 bushels shells planted in 3 rows across the current.	Aug. 18, 1901 Sept. 9, 1902 Aug. 24, 1900 May 28, 1901 Aug. 9, 1901 Sept. 11, 1902	117 35 24 117	90 16 8 7	4 5 3 1	5 17 5 1	5 8 4 1	102 81 91 94 161 203 41 530 139 241 141 101 115 38	28 (?) 35 21 26 (?) 39 52 40 (?) 38 52 25 (?) 50
12	do.....	200	June 13, 1900.	do.....	60 bushels shells planted in 2 rows parallel to current.	Aug. 18, 1901 Sept. 9, 1902 Aug. 24, 1900 May 28, 1901 Aug. 9, 1901 Sept. 11, 1902	61 18 56 1	13 6 56 1	20 11 4 2	7 5 1 23	19 7 2 19	102 81 91 94 161 203 41 530 139 241 141 101 115 38	28 (?) 35 21 26 (?) 39 52 40 (?) 38 52 25 (?) 50
13	do.....	400	June 21, 1900. June 25, 1900.	do..... Shells.....	68 bushels shells evenly scattered. 15 bushels oysters from Cross Rock evenly scattered.	Aug. 18, 1901 Sept. 9, 1902 Aug. 24, 1900 May 28, 1901 Aug. 9, 1901 Sept. 11, 1902	59 29 134 68	29 134 68 68	68 2 8 2	23 19 7 2	7 2 19 7	102 81 91 94 161 203 41 530 139 241 141 101 115 38	28 (?) 35 21 26 (?) 39 52 40 (?) 38 52 25 (?) 50
14	Newport River.	400	June 30, 1900.	Mud.....	70 bushels shells evenly scattered.	Aug. 18, 1901 Sept. 9, 1902 Aug. 24, 1900 May 28, 1901 Aug. 9, 1901 Sept. 11, 1902	59 29 134 68	29 134 68 68	68 2 8 2	23 19 7 2	7 2 19 7	102 81 91 94 161 203 41 530 139 241 141 101 115 38	28 (?) 35 21 26 (?) 39 52 40 (?) 38 52 25 (?) 50
15	do.....	400	July 8, 1900.	do.....	67 bushels shells planted in 4 rows across the current.	Aug. 18, 1901 Sept. 9, 1902 Aug. 24, 1900 May 28, 1901 Aug. 9, 1901 Sept. 11, 1902	59 29 134 68	29 134 68 68	68 2 8 2	23 19 7 2	7 2 19 7	102 81 91 94 161 203 41 530 139 241 141 101 115 38	28 (?) 35 21 26 (?) 39 52 40 (?) 38 52 25 (?) 50
16	North River....	500	July 6, 1900.	do.....	70 bushels shells evenly scattered.	Aug. 18, 1901 Sept. 9, 1902 Aug. 24, 1900 May 28, 1901 Aug. 9, 1901 Sept. 11, 1902	59 29 134 68	29 134 68 68	68 2 8 2	23 19 7 2	7 2 19 7	102 81 91 94 161 203 41 530 139 241 141 101 115 38	28 (?) 35 21 26 (?) 39 52 40 (?) 38 52 25 (?) 50

Planted oysters not distinguishable from those grown on bed.

100 per cent of planted oysters living.

28 per cent of planted oysters living.

75 per cent of planted oysters living.

24 per cent of planted oysters living.

Practically all of the planted oysters dead.



## Detailed record of planting experiments in Newport and North rivers—Continued.

Num- ber of exper- iment.	Location of planted area.	Size of bed.	Date of planting.	Kind of bottom.	Method of planting.	Date of examination.	Oysters less than 1 inch in length attached to—		Oysters be- tween 1 and 2 inches in length at- tached to—		Oysters be- tween 2 and 3 inches in length at- tached to—		Oysters more than 3 inches in length at- tached to—		Total number of living oys- ters attached to 100 plant- ed shells.	Total number of dead oys- ters attached to 100 plant- ed shells.	
							Concave surface.	Convex surface.	Concave surface.	Convex surface.	Concave surface.	Convex surface.	Concave surface.	Convex surface.			
17	Newport River.	Sq. ft. 240	July 10, 1900.	Mud.....	30 bushels shells planted in 3 rows parallel to cur- rents.	Aug. 28, 1900 June 4, 1901 Aug. 9, 1901 Sept. 12, 1902	81 4 12 3	75 8 10 3	148 60 6 297	103 67 10 172	52 46 112 2	88 84 72 4	8 13 7 16	2 7 2	497 240 234 60	14 10 (?) 10	
18	do	300	do	do	33 bushels shells planted in 3 rows across the cur- rents.	Aug. 28, 1900 June 4, 1901 Aug. 17, 1901	108 108 4	91 2 14	297 77 30	172 62 112	44 5 94	5 1 8	13		687 308 273	40 30 (?)	
19	North River	400	July 14, 1900.	do	40 bushels shells planted in 3 rows across the cur- rents.	Aug. 24, 1900 June 6, 1901 Sept. 12, 1902	25 6 17	6 6 11	7 2 2	2 31 2	6 12 3	3 26 1	3 18 2		38 57 49	4 30 14	
20	do	120	do	do	20 bushels shells planted in 2 rows parallel to cur- rents.	Aug. 24, 1900 May 30, 1901 Sept. 9, 1902	54 21 2	14 2 98	14 2 186	9 2 102	4 9 12	1 17 3	5 25 1	5	66 455 183	28 29 (?)	
21	Newport River.	400	July 19, 1900.	do	60 bushels shells evenly scattered.	Aug. 28, 1900 Aug. 13, 1901 Sept. 15, 1902	161 88 69	88 46 4	15 15 12	8 8 11	98 per cent of planted oysters living. 50 per cent of planted oysters living.	98 per cent of planted oysters living. Planted oysters indistinguishable from those grown on bed.	98 per cent of planted oysters living. Planted oysters indistinguishable from those grown on bed.	98 per cent of planted oysters living.	98 per cent of planted oysters living.	98 per cent of planted oysters living.	98 per cent of planted oysters living.
22	do	400	July 20, 1900.	Mud.....	10 bushels oysters from Gallants Reef evenly scattered.	Aug. 28, 1900 Aug. 13, 1901 Sept. 4, 1902	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98
23	do	400	June 11, 1901.	do	10 bushels oysters from Turtle Rock evenly scattered.	Aug. 28, 1900 Aug. 13, 1901 Sept. 15, 1902	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98	98 88 98
24	do	200	do	do	40 bushels shells planted in 4 rows across the cur- rents.	Aug. 6, 1901 Sept. 12, 1902	50 10	2 2	4 4	18 12	11 11	13 22	14 37	30 198	80 12	21 85	24
	do	200	do	do	20 bushels shells planted in 2 rows parallel to currents.	Aug. 6, 1901 Sept. 13, 1902	2 13	2 13	4 20	4 9	8 9	6 10	3 5	12 85	12 85	24	24

[illegible]

## SUMMARY OF WORK AND RESULTS.

In all, 31 beds were made, 18 in Newport River and 13 in North River, representing five methods of planting. On 9 of the beds shells in various quantities were first evenly scattered over the bottom, upon which seed oysters were to be planted. The seed oysters were obtained in different localities and represented various conditions of growth. Some were taken from reefs, and were "coon;" some were tonged from beds known to produce the best marketable oysters of the section; some were obtained from localities where the water usually has a higher specific gravity than that over the experimental beds, and some came from beds over which the water is fresher than on the planted beds. In one instance seed oysters were planted on an unprepared bottom.

The results from planting seed oysters are as follows (an average from the results of all the plants made): At the end of the first season 78 per cent of the oysters were living, but very few were in a growing condition. At the end of the second season 41 per cent only remained alive. Those planted in North River showed no growth and were very poor; those in Newport River, however, had been growing nicely. At the end of the third season no estimate could be made, as it was not possible to distinguish between the oysters which were planted and those which had grown from spat on the beds. The "coon" oysters, planted on 5 of the beds, showed no improvement in shape, and a larger per cent of them died than of the better shaped seed.

Should the same number of new plantings be made, with the methods used in 4, 9, and 22, there is every reason to believe the result would be much more favorable. The per cents given above are cut down very considerably by the results on the beds which were total failures.

Shells were planted in an even layer from 1 to 4 shells in thickness on 6 beds for the purpose of catching spat. To this number may be added the 9 beds which were hardened with shells as a foundation before planting seed oysters, for spat attached to the shells of these beds, and they were regularly examined. The average number of spat counted on a hundred shells tonged from each of these 15 beds at the end of the first season was 97. The number of spat and oysters on the same number of shells taken in the same manner from the same beds at the end of the second season was 157. At the end of the season of 1902, a majority of the oysters were 2 or more inches in length, the total number per hundred shells being 58.

On 9 beds shells were planted in ridges parallel to the currents flowing over them, and on 6, ridges of shells were made across the currents. Examination of the shells from the beds on which the ridges were placed across the currents showed that each hundred shells had caught 303 spat at the end of the first season. (In all the figures none but

living oysters are included.) At the end of the second and third seasons the number of spat and oysters on each hundred shells was 163 and 87, respectively. The shells planted in ridges parallel to the currents caught fewer spat than those planted in ridges making a right angle with the direction of flow, but under both conditions too much spat was caught and coony oysters were in many cases the result. The average catch of spat on each hundred shells on the parallel ridges for the first, second, and third seasons was 221, 150, and 64, respectively. The growth of the oysters which caught to the shells was remarkably rapid, as is shown by the fact that from one of the beds on which no seed were planted, oysters were available for use toward the close of the season of 1902.

From April to September in 1900 large numbers of spat became attached to shells whenever and wherever planted, but the tabulated results of the examinations show that the conditions for their attachment and growth were more favorable in Newport than in North River. The shells on both experimental beds became the home also of innumerable barnacles, crabs, worms, polyzoa, ascidians, sponges, anemones, leptogordias, mussels, and various algæ. During the second year, however, the water became brackish, and all of these animals were killed except the barnacles, crabs, and mussels, which, like the oyster, are adapted to such conditions. The freshness of the water had a decided effect upon the catch of spat also, the number that became attached in Newport River being much smaller than during the previous year, while in North River exactly the opposite occurred. From this it appears that the most favorable conditions for the life of oyster larvæ and their attachment are brought about in North River during a wet season and in Newport River during a drought. This conclusion is borne out by the results during the following dry season of 1902, when the number of oysters that attached to shells on the Newport River bed was much greater than in 1901, while in North River it fell far short.

#### CONCLUSIONS.

The results of the experiments are, on the whole, satisfactory. Several important facts have been demonstrated which can not fail to have a bearing upon any future operations in oyster culture in North Carolina. The lower parts of Newport and North rivers are not adapted to oyster culture. Oysters grow there in abundance when supported above the mud, but there is too much uncertainty connected with the crop to justify practical planting operations. When the time comes to place the oysters on the market they are too often not in salable condition. This is traceable to the high density of the water of these portions of the rivers. Should the industry in Pamlico Sound ever be developed to such an extent as to create a demand for seed oysters, however, the ground in the lower parts of these rivers

will become valuable, for when cultch is exposed a good catch of spat is almost a certainty.

The upper parts of the rivers, on the other hand, are well adapted to oyster planting and, during all but the very dry seasons, there is every reason to believe that planters would be able to market their crop. The industry could never be extensive on account of the small amount of available ground, but between the natural beds there are many acres that might be utilized for purposes of planting. The natural beds themselves, if strewn with shells at some time during the summer months, could easily be made to yield many times the amount of oysters that is annually taken from them. They are public property, and no individual can be expected to be so public spirited as to as to plant the shells, but it might be done by the State, in one instance at least, as an experiment.

It is better to strew shells and stock beds from spat than to plant large seed oysters. The latter do not recover from the shock they have undergone in the rough handling and in the sudden change in their habitat until spat caught at the time of planting the seed oysters have attained an equal size.

Under favorable conditions some oysters may be marketed the third season after the shells are put down. Oysters of excellent shape,  $2\frac{1}{2}$  inches in length, can be raised in abundance in one year from the date of planting shells. Such oysters are well suited to the half-shell trade, and a profitable industry for a limited number of planters might be developed along this line.

When oysters are planted, the stock should be young, as it then more readily adapts itself to new conditions than does old seed. Large "coony" oysters are worthless as seed, since they are incapable of improvement, even when planted in the most favorable environment. Very badly shaped young oysters, however, soon regain their normal shape when placed under favorable conditions, as has been shown by Mr. Glaser in some experiments carried on in 1902, and which are described by him on page 329 of this report.

Shells intended as spat collectors (in Newport and North rivers) should be strewn over the bottom rather than planted in rows. In the latter case too much spat usually becomes attached, and "coony" oysters are the result. The proper amount of shells to be planted should be determined by the character of the bottom. The softer and deeper the mud the more shells should be used. In no case should less than 2,000 bushels per acre be planted, but the cases are few where more than 5,000 bushels would be needed. Using the first amount, the bottom would be covered with a layer one shell in thickness. The aim should be to plant enough shells to prevent those on top from settling below the surface. In the greater number of the experiments the results show that too many shells have been used.

June and July are the best months in which to plant shells intended as spat collectors, although a set was secured upon shells planted from April to September. Spat also attached during the summers of 1901 and 1902 to shells planted in 1900.

Shells or oysters should never be planted on a sandy bottom in Newport or North rivers. This conclusion will probably not apply to sandy bottoms in Pamlico Sound, where the sand is often held together by grass roots and thus prevented from shifting.

Steamed oyster shells make excellent spat collectors. They are cheap and are available in immense quantities at various accessible points on the North Carolina coast.

Oyster planting should not be undertaken by any but experienced oystermen. So much depends upon the selection of the site and upon the methods of planting and caring for the beds that failure must be regarded as the probable result of careless work.

#### OYSTER PLANTING IN PAMLICO SOUND.

Numerous attempts have been made from time to time at many places in Pamlico Sound to establish private oyster grounds, but as yet they have not proved successful.

The following table, compiled by Mr. C. H. Stevenson, shows the approximate number and the extent of the grants in Pamlico Sound for the purpose of oyster culture since 1872. It must be remembered that this enumeration does not include the enormous number of entries made, but for which grants have never been asked. Under the enactment of 1887 as many as 1,067 entries were made in Hyde County alone:

*Grants for oyster culture in Pamlico Sound.*

Year.	Dare County.		Hyde County.		Pamlico County.	
	Grants.	Acres.	Grants.	Acres.	Grants.	Acres.
1873.....			1	8		
1875.....			2	17		
1876.....			8	82		
1877.....			3	27		
1878.....					1	9
1879.....					2	17
1880.....			1	10		
1881.....					2	19
1882.....	2	18	1	9		8
1884.....	18	171			3	27
1885.....	4	37	6	55	12	101
1886.....	3	16			8	76
1887.....			2	12		
1888.....			10	69		
1889.....	6	56	153	1,888		
1890.....	21	201	28	250		
1891.....	3	28	23	216	8	80
1892.....			22	230		
1893.....			10	100		
1894.....	1	10	35	330		
1895.....	2	16				
Total.....	80	553	305	2,603	37	337

In 1900 practically all of these grounds had been abandoned by the owners. Those which are held and on which the taxes had been paid were as follows:

*Oyster grants on which taxes were paid.*

	Number.	Acres.
Hyde County:		
Lake Landing .....	56	477
Ocracoke .....	7	41
Swan Quarter .....	3	162
Pamlico County:		
Township No. 2 .....	6	74
Township No. 4 .....	1	80
Total .....	73	834

The causes of this condition of the industry in Pamlico Sound, judging from its history here and in other oyster-producing sections, are:

(1) Those who have engaged in it have, as a rule, had erroneous ideas as to the requirements for successful oyster culture. They were not aware how very much depends upon the selection of ground, the accessibility of an abundant food supply, the specific gravity of the water and its freedom from extreme fluctuations, the time and methods of planting cultch and oysters, etc.

(2) Many of those who entered ground for oyster planting did so with the expectation that large profits would be immediately forthcoming, and were not sufficiently interested to continue in the work when they had ascertained by experience that this is no more profitable than other industries and requires a corresponding amount of time and labor.

(3) The laws framed for the encouragement and protection of oyster culture were defective or have not been observed.

Private grounds in Pamlico Sound have in many cases proved to have been well selected and have produced oysters of a good quality, but the owners of such grounds have, in some notable instances, not been allowed to market the crop; they have been powerless to prevent their grounds from being treated as public property. Oystermen when arrested for trespassing in such cases have been able, invariably, to obtain their release without fine or imprisonment by asserting that the planted grounds when laid off contained natural oyster beds, and no difficulty has been experienced by them in finding a multitude of witnesses to substantiate their statements; this in spite of the fact that careful surveys of the grounds previous to obtaining grants or planting the oysters failed to discover any natural oyster beds.

From a biological standpoint Pamlico Sound offers a wide and promising field for oyster culture. The results of the survey of sections 10 and 16 demonstrate beyond doubt that (a) oyster food is abundant in these sections; (b) many localities exist not now occupied by oysters

in which the water has the necessary specific gravity and is not readily disturbed by freshets; (c) oysters have grown as well when transplanted to ground adjoining natural beds as on the natural beds themselves; and (d) in the regions where natural beds exist spat can be secured if cultch be supplied.

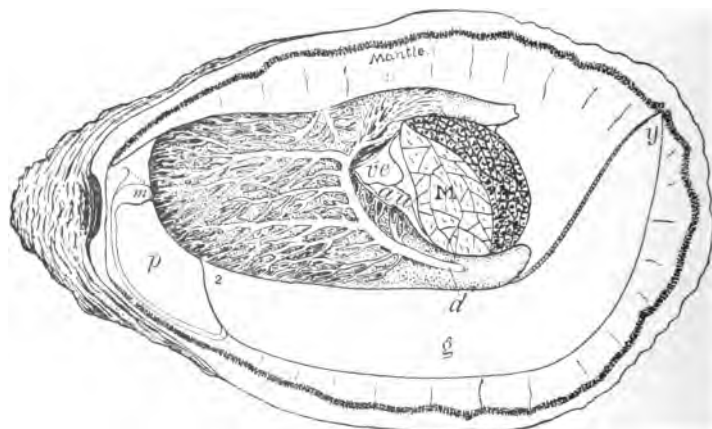
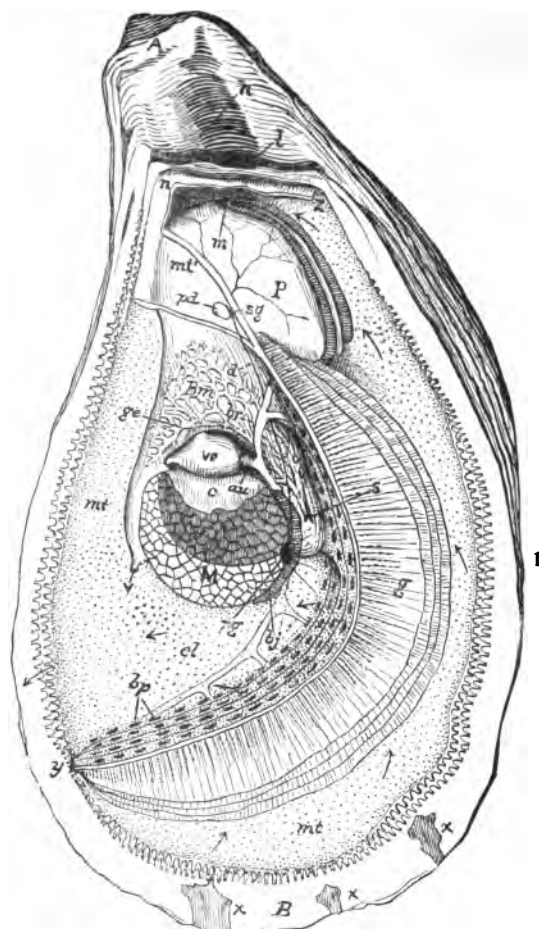
If it is the wish of the people of North Carolina to encourage the development of an industry in oyster culture it can be accomplished (1) by amending the laws relating to the entry of grounds for this purpose; (2) by creating a proper sentiment in this direction, and (3) by supplying to the people of eastern North Carolina accurate information relative to all phases of the subject.

To aid in the accomplishment of this result has been the object and purpose of the North Carolina Geological Survey and the United States Fish Commission in conducting the survey and experiments of which this is the final report, and in conducting the further investigations now under way in Pamlico Sound, the results of which will soon be ready for publication.









2

FIG. 1. Oyster with right shell and mantle removed. *a* and *a'*, origin of arteries from the ventricle; *au*, auricle of heart; *br*, vessel carrying kidney blood from the gills to the auricle of the heart; *bj*, outline of organ of Bojanus, the so-called kidney; *bp*, pores from which the water issues into the branchial canals after passing through the gills; *cl*, cloaca; *d*, *pg*, and *sg*, connective and two ganglia of the nervous system; *g*, gills; *gc*, cavity between the two mantle folds; *h*, hinge; *l*, ligament. *M*, adductor muscle; *m*, mouth; *mt*, mantle, the arrows show the direction of currents produced by the cilia; *p*, palps; *p'*, outer end of right pedal muscle; *s*, external opening of sexual and renal organs of right side; *v*, anus; *ve*, ventricle of heart.

FIG. 2. Diagram to show sexual organs of the oyster. *d*, duct of sexual gland. Other letters as above.

# ANATOMY, EMBRYOLOGY, AND GROWTH OF THE OYSTER.

By H. F. MOORE.<sup>a</sup>

## ANATOMY.

The following popular description of the anatomy of the oyster is extracted from the writings of Professors Brooks and Ryder:

The general structure of an oyster may be roughly represented by a long, narrow memorandum book, with the back at one of the narrow ends instead of one of the long ones. The covers of such a book represent the two shells of the oyster, and the back represents the hinge, or the area where the two valves of the shell are fastened together by the hinge ligament. (Plate VII, fig. 1 l.) This ligament is an elastic, dark-brown structure, which is placed in such a relation to the valves of the shell that it tends to throw their free ends a little apart. In order to understand its manner of working, open the memorandum book and place between its leaves, close to the back, a small piece of rubber to represent the ligament. If the free ends of the cover are pulled together the rubber will be compressed and will throw the covers apart as soon as they are loosened. The ligament of the oyster shell tends, by its elasticity, to keep the shell open at all times, and while the oyster is lying undisturbed upon the bottom, or when its muscle is cut, or when the animal is dying or dead, the edges of the shell are separated a little.

The shell is lined by a thin membrane, the mantle (plate VII, fig. 1 *mt*), which folds down on each side, and may be compared to the leaf next the cover on each side of the book. The next two leaves of each side roughly represent the four gills, *g*, the so-called "beard" of the oyster, which hang down like leaves into the space inside the two lobes of the mantle. The remaining leaves may be compared to the body or visceral mass of the oyster.

Although the oyster lies upon the bottom, with one shell above and one below, the shells are not upon the top and bottom of the body, but upon the right and left sides. The two shells are symmetrical in the young oyster (plate VIII, fig. 2), but after it becomes attached the lower or attached side grows faster than the other, and becomes deep and spoon-shaped, while the free valve remains nearly flat. In nearly every case the lower or deep valve is the left. As the hinge marks the anterior end of the body, an oyster which is held on edge, with the hinge away from the observer, and the flat valve on the right side, will be placed with its dorsal surface uppermost, its ventral surface below, its anterior end away from the observer, and its posterior end toward him, and its right and left sides on his right and left hands, respectively.

In order to examine the soft parts, the oyster should be opened by gently working a thin, flat knife-blade under the posterior end of the right valve of the shell, and pushing the blade forward until it strikes and cuts the strong adductor muscle, *M*, which passes from one shell to another and pulls them together. As soon as this

<sup>a</sup> Reprinted from "Oysters and Methods of Oyster Culture," Report U. S. Fish Commission, 1897, pp. 270-279.

muscle is cut the valves separate a little, and the right valve may be raised up and broken off from the left, thus exposing the right side of the body. The surface of the body is covered by the mantle, a thin membrane which is attached to the body over a great part of its surface, but hangs free like a curtain around nearly the whole circumference. By raising its edge, or gently tearing the whole right half away from the body, the gills, *g*, will be exposed. These are four parallel plates which occupy the ventral half of the mantle cavity and extend from the posterior nearly to the anterior end of the body. Their ventral edges are free, but their dorsal edges are united to each other, to the mantle, and to the body. The space above, or dorsal to the posterior ends of the gills, is occupied by the oval, firm adductor muscle, *M*, the so-called "heart." For some time I was at a loss to know how the muscle came to be called the "heart," but a friend told me that he had always supposed that this was the heart, since the oyster dies when it is injured. The supposed "death" is simply the opening of the shell, when the animal loses the power to keep it shut. Between this muscle and the hinge the space above the gills is occupied by the body, or visceral mass, which is made up mainly of the light-colored reproductive organs and the dark-colored digestive organs, packed together in one continuous mass.

If the oyster has been opened very carefully, a transparent, crescent-shaped space will be seen between the muscle and the visceral mass. This space is the pericardium, and if the delicate membrane which forms its sides be carefully cut away, the heart, *re* and *au*, may be found without any difficulty lying in this cavity and pulsating slowly. If the oyster has been opened roughly, or if it has been out of water for some time, the rate of beating may be as low as one a minute, or even less, so the heart must be watched attentively for some time in order to see one of the contractions.

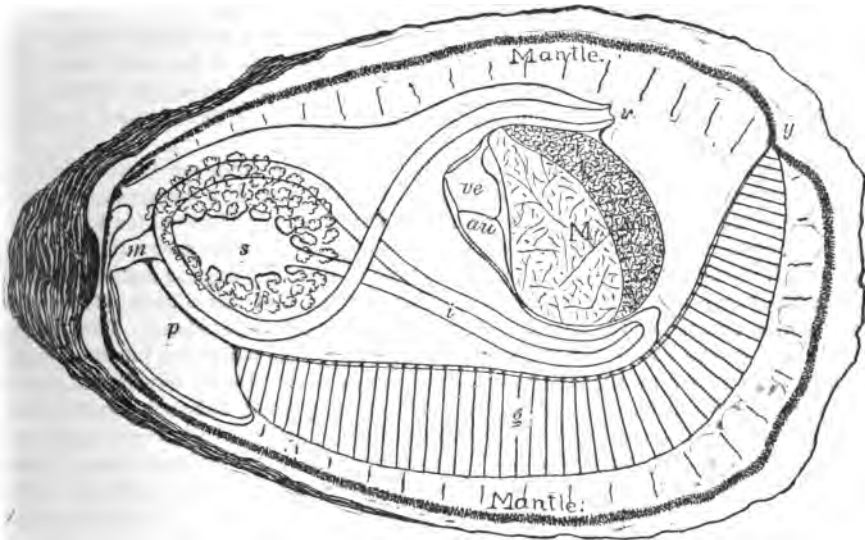
\*                      \*                      \*                      \*                      \*                      \*

In front of the gills, that is between them and the hinge, there are four fleshy flaps—the lips, *p*, two on each side of the body. They are much like the gills in appearance, and they are connected with each other by two ridges, which run across the middle of the body close to the anterior end, and between these folds is the large oval mouth, *m*, which is thus seen to be situated, not at the open end of the shell, but as far away from it as possible. As the oyster is immovably fixed upon the bottom, and has no arms or other structures for seizing food and carrying it to the mouth, the question how it obtains its food at once suggests itself. If a fragment of one of the gills is examined with a microscope it will be found to be covered with very small hairs, or cilia, arranged in rows, plate ix, fig. 3, *c*. Each of these cilia is constantly swinging back and forth with a motion something like that of an oar in rowing. The motion is quick and strong in one direction and slower in the other. As all the cilia of a row swing together they act like a line of oars, only they are fastened to the gill, and as this is immovable they do not move forward through the water, but produce a current of water in the opposite direction. This action is not directed by the animal, for it can be observed for hours in a fragment cut out of the gill, and if such a fragment be supplied with fresh sea water the motion will continue until it begins to decay. While the oyster lies undisturbed on the bottom, with its muscle relaxed and its shell open, the sea water is drawn on to the gills by the action of the cilia, for although each cilium is too small to be seen without a microscope, they cover the gills in such great numbers that their united action produces quite a vigorous stream of water, which is drawn through the shell and is then forced through very small openings on the surfaces of the gills into the water tubes inside the gills, and through these tubes into the cavity above them, and so out of the shell again. As the stream of water passes through the gills the blood is aerated by contact with it.

The food of the oyster consists entirely of minute animal and vegetable organisms and small particles of organized matter. Ordinary sea water contains an abundance of this sort of food, which is drawn into the gills with the water, but as the water

strains through the pores into the water tubes the food particles are caught on the surface of the gills by a layer of adhesive slime, which covers all the soft parts of the body. As soon as they are entangled the cilia strike against them in such a way as to roll or slide them along the gills toward the mouth. When they reach the anterior ends of the gills they are pushed off and fall between the lips, and these again are covered with cilia, which carry the particles forward until they slide into the mouth, which is always wide open and ciliated, so as to draw the food through the œsophagus into the stomach. Whenever the shell is open these cilia are in action, and as long as the oyster is breathing a current of food is sliding into its mouth.

The cilia and particles of food are too small to be seen without a microscope, but if finely powdered carmine be sprinkled over the gills of a fresh oyster, which has been carefully opened and placed in a shallow dish of sea water, careful observation will show that as soon as the colored particles touch the gills they begin to slide along with a motion which is quite uniform, but not much faster than that of the



minute-hand of a watch. This slow, steady, gliding motion, without any visible cause, is a very striking sight, and with a little care the particles may be followed up to and into the mouth.

In order to trace the course of the digestive organs the visceral mass may be split with a sharp knife or razor. If the split is pretty near the middle of the body, each half will show sections of the short, folded œsophagus, running upward from the mouth and the irregular stomach, *s* (see cut) with thick, semitransparent walls, surrounded by the compact, dark-greenish liver, *ll*. Back of the liver and stomach the convoluted intestine, *i*, will be seen, cut irregularly at several points by the section.

There are no accessory organs of reproduction, and the position, form, and general appearance of the reproductive organ, plate VII, fig. 2, is the same in both sexes. As the reproductive organ has an opening on each side of the body, it is usually spoken of as double, but in the adult oyster it forms one continuous mass, with no trace of a

division into halves, and extends entirely across the body and (against) the bends and folds of the digestive tract.<sup>a</sup>

\* \* \* \* \*

The stomach is pretty definitely marked off from the other portions of the digestive tract. It may be said to be that portion of the latter which is surrounded by the liver. The portion of the intestine immediately following the short, widened region which we regarded as the stomach is the most spacious portion of the gut, and in it is lodged a very singular organ, which has been called the "crystalline style." This is an opalescent rod of a glass-like transparency and gelatinous consistence, which measures, according to the size of the oyster, from half an inch up to one and a half inches in length. Its anterior end is the largest, and in a large specimen measures nearly an eighth of an inch in diameter, but at its posterior end is scarcely half as thick; both ends are bluntly rounded. I fell into an error in supposing that this style was lodged in a special pouch or sac, as described in my report to the Maryland commissioner in 1880. The "crystalline style" really lies in the first portion of the intestine and extends from the pyloric end of the stomach to the first bend of the intestine, where there is a marked constriction of the alimentary canal. It appears, therefore, to be a sort of loose valve in the cavity of the gut; its function may be to prevent coarse particles of food from passing, or it may in some way assist digestion. In specimens hardened in acid or alcohol this rod is destroyed, or at least disappears, so that I have been unable to find it. The greater portion of its substance is apparently made up of water.

The peculiar double induplication of the wall of the intestine is described in another place. The fecal matters are extruded in the form of a demicylinder, with one side excavated in a groove-like manner. This shape of the fecal matters is due to the presence of the double fold. The feces themselves are composed of extremely fine particles of quartz or sand grains, the tests of diatoms, organic matter, humus, cellulose, fragments of the chitinous coverings of some of the minute worms and articulates, etc., which have been swallowed and digested by the animal. The anus, *r*, is situated on the dorsal side of the great adductor muscle where the intestine ends.

The organs of sensation of the oyster, though not very highly developed, are of sufficient importance to merit attention. The auditory sense, although I have never been able to dissect out the auditory vesicles, I am satisfied exists, because one can not noisily approach an oyster bank where the oysters are feeding without their hearing so that instantly every shell is closed. The tentacles of the mantle are often extended until their tips reach beyond the edges of the valves. If the animal in this condition is exposed to a strong light, the shadow of the hand passing over it is a sufficient stimulus to cause it to retract the mantle and tentacles and to close its parted valves. The mantle incloses, like a curtain, the internal organs of the creature on either side, and lies next the shell, and, as already stated, secretes and deposits the layers of calcic carbonate composing the latter. The free edges of the mantle, which are purplish, are garnished with small, highly sensitive tentacles of the same color. These tentacles are ciliated and serve as organs of touch, and also appear to be to some extent sensitive to light.

The nervous system of the oyster is very simple, and, as elsewhere stated, is to some extent degenerate in character. It is composed of a pair of ganglia or knots of nervous matter, plate VII, fig. 1, *sg*, which lie just over the gullet, and from these a pair of nervous cords, *d*, pass backward, one on each side, to join the hinder pair which lie just beneath the adductor muscle, *pg*. The mantle receives nerve branches from the hindmost ganglia or knots of nervous matter; these, as their centers, control the contraction and elongation of the radiating bundle of muscular fibers, as well as those which lie lengthwise along the margin; the former contract and withdraw the

<sup>a</sup> Brooks, W. K.: Studies from the Biological Laboratory of Johns Hopkins University, No. IV, 1888, pp. 5-10 in part.



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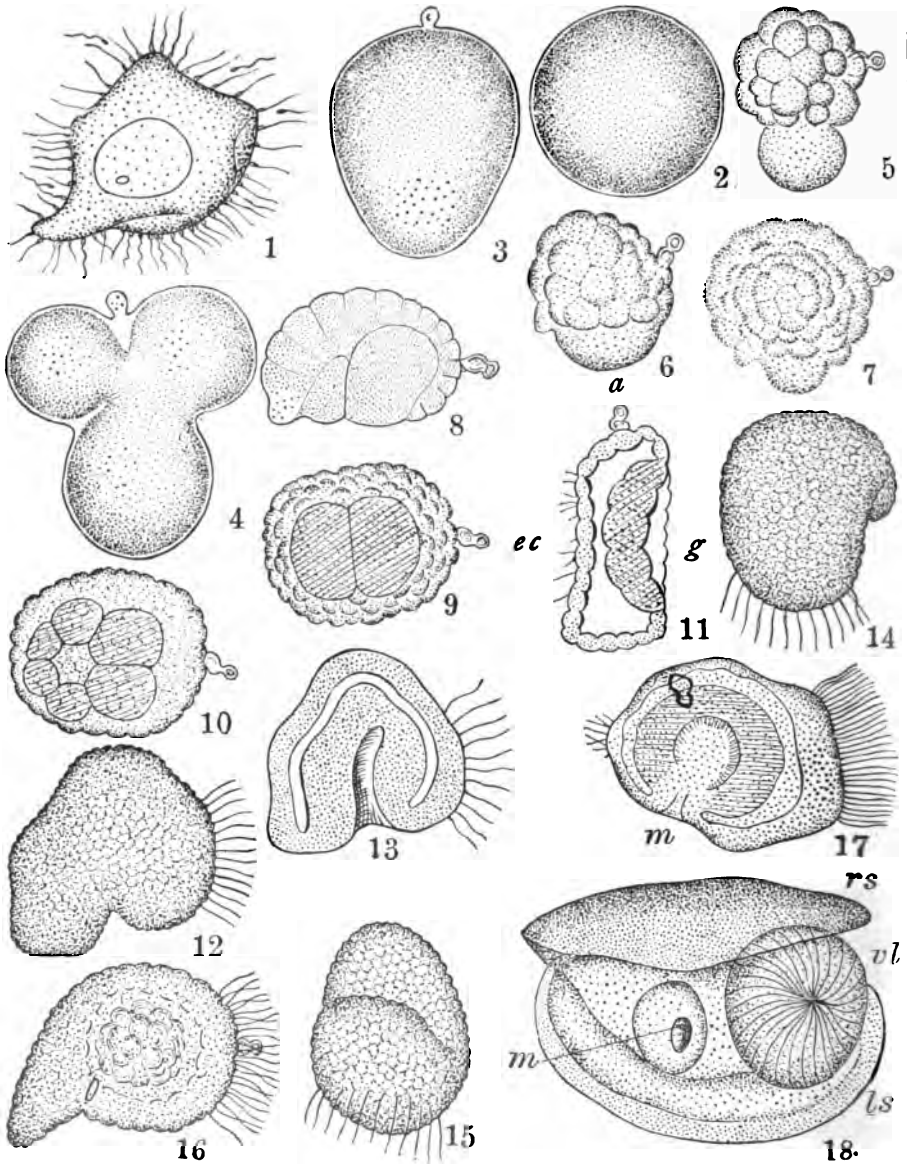


FIG. 1. Unfertilized egg shortly after mixture of spawn and milt; spermatozoa are adhering to the surface.

FIG. 2. Egg after fertilization.

FIG. 3. Same egg 2 minutes later. Polar body at broad end.

FIG. 4. Same egg 6 minutes later.

FIG. 5. About 6 hours later.

FIG. 6. Another egg at about the same stage. Mass of small cells growing over large cell or macromere *a*.

FIG. 7. Egg 55 minutes later. Macromere almost covered by small cells of ectoderm.

FIG. 8. Optical section of egg 27 hours after impregnation, showing two large cells, derived from *a* in fig 6, covered by a layer of small ectodermal cells.

FIG. 9. Egg a few hours older, showing large cells viewed from below.

FIG. 10. An egg somewhat older viewed from above, showing further subdivision of large cells as seen through cells of upper layer.

FIG. 11. An older egg, now become flattened from above downward. Viewed in optical section.

FIG. 12. Surface view of an embryo just beginning to swim.

FIG. 13. Optical section of same.

FIG. 14. Surface view of same from another position.

FIG. 15. Surface view of same from another position.

FIG. 16. An older embryo in same position as in fig 12

FIG. 17. A still older embryo showing spherical ciliated digestive cavity opening by mouth, *m*.

FIG. 18. An embryo with well-developed larval shells, older than fig. 1, Plate VIII. *rs*, right shell; *ls*, left shell; *vl*, velum; *m*, mouth.

After W. K. Brooks.

edges of the mantle from the margin of the shell, while the latter in contracting tend to crimp or fold its edges. The tentacles are mainly innervated by fibers emanating from the hindmost ganglia, while the internal organs are innervated from the head or cephalic ganglia. The hind ganglia also preside over the contraction of the great adductor muscle. The nerve threads which radiate outward from it to the tentacles dispatch the warnings when intruders are at hand that it must contract and close the shells.<sup>a</sup>

#### EMBRYONIC DEVELOPMENT.

The following popular account of the early stages in the development of the oyster is slightly modified from the description by Dr. W. K. Brooks:

The ovarian eggs are simply the cells of an organ of the body, the ovary, and they differ from the ordinary cells only in being much larger and more distinct from each other, and they have the power, when detached from the body, of growing and dividing up into cells, which shall shape themselves into a new organism like that from whose body the egg came. Most of the steps in this wonderful process may be watched under the microscope, and, owing to the ease with which the eggs of the oyster may be obtained, this is a very good egg to study.

About 15 minutes after the eggs are fertilized they will be found to be covered with male cells, as shown in plate VIII, fig. 1.<sup>b</sup> In about an hour the egg will be found to have changed its shape and appearance. It is now nearly spherical, as shown in plate VIII, fig. 2, and the germinative vesicle is no longer visible. The male cells may or may not still be visible upon the outer surface. In a short time a little transparent point makes its appearance on the surface of the egg and increases in size and soon forms a little projecting transparent knob—the *polar globule*—which is shown in fig. 3, plate VIII, and in succeeding figures.

Recent investigations tend to show that while these changes are taking place one of the male cells penetrates the protoplasm of the egg and unites with the germinative vesicle, which does not disappear but divides into two parts, one of which is pushed out of the egg and becomes the polar globule, while the other remains behind and becomes the nucleus of the developing egg, but changes its appearance so that it is no longer conspicuous. The egg now becomes pear-shaped, with the polar globule at the broad end of the pear, and this end soon divides into two parts, so that the egg (fig. 4, plate VIII) is now made of one large mass and two slightly smaller ones, with the polar globule between them.

The later history of the egg shows that at this early stage the egg is not perfectly homogeneous, but that the protoplasm which is to give rise to certain organs of the body has separated from that which is to give rise to others.

The upper portion of the egg soon divides up into smaller and smaller spherules, until at the stage shown in figs. 5, 6, and 7, plate VIII, we have a layer of small cells wrapped around the greater part of the surface of a single large spherule, and the series of figures shows that the latter is the spherule which is below in fig. 4, plate VIII. This spherule now divides up into a layer of cells, and at the same time the egg, or rather the embryo, becomes flattened from above downward and assumes the shape of a flat oval disk. Figs. 10 and 9, plate VIII, are views of the upper and lower surface of the embryo at about this time. In a sectional view, fig. 11, plate VIII, it is seen to be made of two layers of cells, an upper layer of small transparent cells, *e c*, which are

<sup>a</sup> Ryder, John A.: Fishery Industries of the United States, pp. 714-715.

<sup>b</sup> References to figures in quoted portions of this paper do not correspond with the originals, being altered to accord with their sequence in the present article.

to form the outer wall of the body and which have been formed by the division of the spherules which occupy the upper end of the egg in fig. 6, plate VIII, and a lower layer of much larger, more opaque cells, *g*, which are to become the walls of the stomach, and which have been formed by the division of the large spherule, *a*, of fig. 6, plate VIII.

This layer is seen in the section to be pushed in a little toward the upper layer, so that the lower surface of the disk-shaped embryo is not flat, but very slightly concave. This concavity is destined to grow deeper until its edges almost meet, and it is the rudimentary digestive cavity. A very short time after this stage has been reached, and usually within from two to four hours after the eggs were fertilized, the embryo undergoes a great change of shape and assumes the form which is shown in three different views in figs. 12, 13, 14, and 15, plate VIII.

A circular tuft of long hairs or cilia has now made at its appearance at what is thus marked as the anterior end of the body, and as soon as these hairs are formed they begin to swing backward and forward in such a way as to constitute a swimming organ, which rows the little animal up from the bottom to the surface of the water, where it swims around very actively by the aid of its cilia. This stage of development, fig. 12, plate VIII, which is of short duration, is of great importance in raising the young oysters, for it is the time when they can best be siphoned off into a separate vessel and freed from the danger of being killed by the decay of any eggs which may fail to develop. On one surface of the body at this stage, the dorsal surface, there is a well-marked groove, and when a specimen is found in a proper position for examination the opening into the digestive tract is found at the bottom of this groove. Fig. 13, plate VIII, is a sectional view of such an embryo. It is seen to consist of a central cavity, the digestive cavity, which opens externally on the dorsal surface of the body by a small orifice, the primitive mouth, and which is surrounded at all points, except at the mouth, by a wall which is distinct from the outer wall of the body. Around the primitive mouth these two layers are continuous with each other.

The way in which this cavity, with its wall and external opening, has been formed will be understood by a comparison of fig. 13, plate VIII, with fig. 8, plate VIII. The layer which is below in fig. 8, plate VIII, has been pushed upward in such a way as to convert it into a long tube, and at the same time the outer layer has grown downward and inward around it, and has thus constricted the opening. The layer of cells which is below in fig. 8, plate VIII, thus becomes converted into the walls of the digestive tract, and the space which is outside and below the embryo, in fig. 8, plate VIII, becomes converted into an inclosed digestive cavity, which opens externally by the primitive mouth.

This stage of development, in which the embryo consists of two layers, an inner layer surrounding a cavity which opens externally by a mouth-like opening, and an outer layer which is continuous with the inner around the margins of the opening, is of very frequent occurrence, and it has been found, with modifications, in the most widely separated groups of animals, such as the starfish, the oyster, and the frog; and some representatives of all the larger groups of animals, except the protozoa, appear to pass during their development through a form which may be regarded as a more or less considerable modification of that presented by our embryo oyster. This stage of development is known as the *gastrula* stage.

The edges of the primitive mouth of the oyster continue to approach each other and finally meet and unite, thus closing up the opening, as shown in fig. 16, plate VIII, and leaving the digestive tract without any communication with the outside of the body, and entirely surrounded by the outer layer. The embryo shown in figs. 12 and 16, plate VIII, are represented with the dorsal surface below, in order to facilitate comparison with the adult, but in fig. 17, plate VIII, and most of the following figures, the dorsal surface is uppermost, for more ready comparison with the adult.



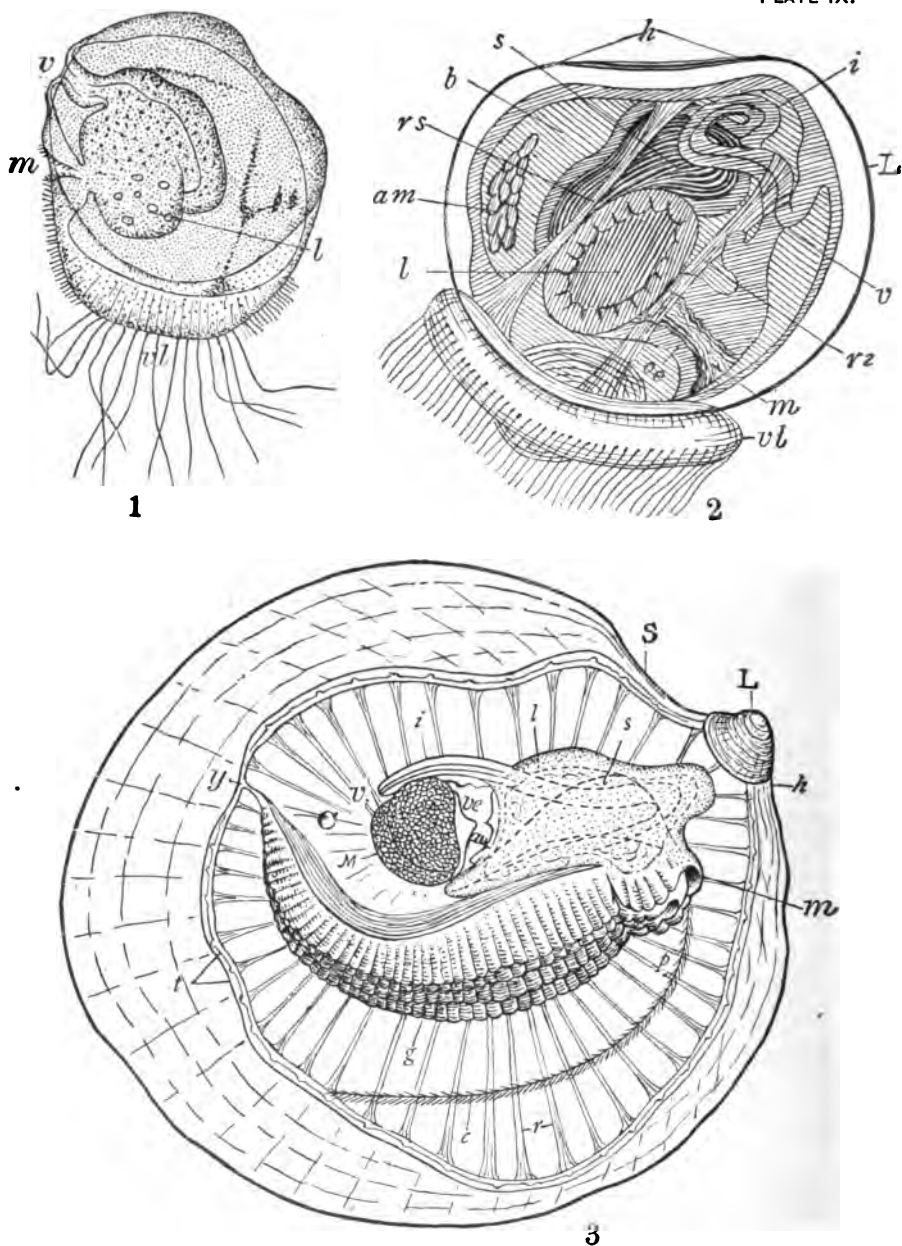


FIG. 1. View of right side of embryo about 6 days old. *m*, mouth; *v*, vent; *l*, right lobe of liver; *vl*, velum.  
 FIG. 2. Older larva of European oyster, *Ostrea lurida*. *L*, shell; *h*, hinge; *rs* and *ri*, retractor muscles of the velum; *vl*, *s*, stomach; *i*, intestine; *am*, larval adductor muscle; *b*, body cavity. Other letters as in the preceding.  
 FIG. 3. Attached spat of *Ostrea virginica*. *S*, shell of spat with larval shell, *L*, at the beak or umbo; *p*, palps; *g*, gills; *c*, diagrammatic representation of a single row of cilia extending from the mantle border to the mouth *m*; *r*, radiating muscle fibres of mantle; *t*, rudimentary tentacles of mantle border; *M*, permanent adductor muscle; *C*, cloaca; *ve* and *au*, ventricle and auricle of the heart; *y*, posterior extremity of the gills and junction of the mantle folds. Other figures as above. Compare this figure with Pl. I, fig. 1.

Fig. 1 after W. K. Brooks. Fig. 2 after Thomas H. Huxley. Fig. 3 after John A. Ryder.

In other lamellibranchs, and doubtless also in the oyster, the shell begins as a deposit in an invagination or pocket on the dorsal side of the body. In its manner of formation this shell gland resembles the primitive mouth for which it has been more than once mistaken by investigators. In some forms the shell is at first single, but in the oyster the two are said to be separated from each other from the beginning, and appear independently. Doctor Brooks says further:

Soon after they make their appearance, the embryos cease to crowd to the surface of the water and sink to various depths, although they continue to swim actively in all directions, and may still be found occasionally close to the surface. The region of the body which carries the cilia now becomes sharply defined, as a circular projecting pad, the *velum*, and this is present and is the organ of locomotion at a much later stage of development. It is shown at the right side of the figure in plate VIII, fig. 17, and in fig. 18, plate VIII, it is seen in surface view, drawn in between the shells, and with its cilia folded down and at rest, as they are seen when the little oyster lies upon the bottom.

The two shells grow rapidly, and soon become quite regular in outline, as shown in plate VIII, fig. 17, and plate IX, fig. 1, but for some time they are much smaller than the body, which projects from between their edges around their whole circumference, except that along a short area, the area of the hinge upon the dorsal surface, where the two valves are in contact.

The two shells continue to grow at their edges, and soon become large enough to cover up and project a little beyond the surface of the body, as shown in plate IX, fig. 1, and at the same time muscular fibers make their appearance and are so arranged that they can draw the edge of the body and the velum in between the edges of the shells in the manner shown in plate VIII, fig. 18. In this way that surface of the body which lines the shell becomes converted into the two lobes of the mantle, and between them a mantle cavity is formed, into which the velum can be drawn when the animal is at rest. While these changes have been going on over the outer surface of the body other important internal modifications have taken place. We left the digestive tract at the stage shown in plate VIII, fig. 16, without any communication with the exterior.

Soon the outer wall of the body becomes pushed inward to form the true mouth, at a point (plate VIII, fig. 17) which is upon the ventral surface and almost directly opposite the point where the primitive mouth was situated at an earlier stage. The digestive cavity now becomes greatly enlarged and cilia make their appearance upon its walls, the mouth becomes connected with the chamber which is thus formed and which becomes the stomach, and minute particles of food are drawn in by the cilia and can now be seen inside the stomach, where the vibration of the cilia keep them in constant motion. Up to this time the animal has developed without growing, and at the stage shown in plate VIII, fig. 16, it is scarcely larger than the unfertilized egg, but it now begins to increase in size. The stages shown in plate IX, fig. 1, and plate VIII, fig. 18, agree pretty closely with the figures which the European embryologists give of the oyster embryo at the time when it escapes from the mantle chamber of its parent. The American oyster reaches this stage in from twenty-four hours to six days after the egg is fertilized, the rate of development being determined mainly by the temperature of the water.

Soon after the mantle has become connected with the stomach this becomes united to the body wall at another point a little behind the mantle, and a second opening, the anus, is formed. The tract, which connects the anus with the stomach, lengthens and forms the intestine, and soon after the sides of the stomach become folded off to form the two halves of the liver, as shown in plate IX, fig. 1. Various muscular

fibers now make their appearance within the body, and the animal assumes the form shown in plate ix, fig. 1, and plate viii, fig. 18.<sup>a</sup>

What follows this stage may be best told in the words of Professor Huxley, who speaks of the European oyster, in which the metamorphosis from the free-swimming fry to the fixed spat and finally the adult oyster is essentially the same as in our species:

The young animal which is hatched out of the egg of the oyster is extremely unlike the adult, and it will be worth while to consider its character more closely than we have hitherto done.

Under a tolerably high magnifying power the body is observed to be inclosed in a transparent but rather thick shell (plate ix, fig. 2, *L*), composed, as in the parent, of two valves united by a straight hinge, *h*. But these valves are symmetrical and similar in size and shape, so that the shell resembles that of a cockle more than it does that of an adult oyster. In the adult the shell is composed of two substances of different character, the outer brownish, with a friable prismatic structure, the inner dense and nacreous. In the larva there is no such distinction, and the whole shell consists of a glassy substance devoid of any definite structure.

The hinge line answers, as in the adult, to the dorsal side of the body. On the opposite or ventral side the wide mouth *m* and the minute vent *v* are seen at no great distance from one another. Projecting from the front part of the aperture of the shell there is a sort of outgrowth of the integument of what we may call the back of the neck into a large oval thick-rimmed disk termed the *velum*, *vl*, the middle of which presents a more or less marked prominence. The rim of the disk is lined with long vibratile cilia, and it is the lashing of these cilia which propels the animal, and, in the absence of gills, probably subserves respiration. The funnel-shaped mouth has no palps; it leads into a wide gullet, and this into a capacious stomach. A sac-like process of the stomach on either side (the left one, *l*, only is shown in fig. 2) represents the "liver." The narrow intestine is already partially coiled on itself, and this is the only departure from perfect bilateral symmetry in the whole body of the animal. The alimentary canal is lined throughout with ciliated cells, and the vibration of these cilia is the means by which the minute bodies which serve the larva for food are drawn into the digestive cavity.

There are two pairs of delicate longitudinal muscles, *rs ri*, which are competent to draw back the ciliated velum into the cavity of the shell, when the animal at once sinks. The complete closure of the valves is effected, as in the adult, by an adductor muscle, *am*, the fibers of which pass from one valve to the other. But it is a very curious circumstance that this adductor muscle is not the same as that which exists in the adult. It lies, in fact, in the fore part of the body and on the dorsal side of the alimentary canal. The great muscle of the adult, fig. 3, *M*, on the other hand, lies on the ventral side of the alimentary canal and in the hinder part of the body. And as the muscles, respectively, lie on opposite sides of the alimentary canal, that of the adult can not be that of the larva, which has merely shifted its position; for in order to get from one side of the alimentary canal to the other it must needs cut through that organ; but as in the adult no adductor muscle is discoverable in the position occupied by that of the larva or anywhere on the dorsal side of the alimentary canal, while on the other hand there is no trace of any adductor on the ventral side in the larva, it follows that the dorsal or anterior adductor of the larva must vanish in the course of development, and that a new ventral or posterior adductor must be developed to play the same part and replace the original muscle functionally, though not morphologically.

\*            \*            \*            \*            \*            \*            \*

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<sup>a</sup> Report Maryland Fish Commission, Annapolis, 1880, pp. 19-25, in part.

When the free larva of the oyster settles down into the fixed state, the left lobe of the mantle stretches beyond its valve, and, applying itself to the surface of the stone or shell to which the valve is to adhere, secretes shelly matter, which serves to cement the valve to its support. As the animal grows the mantle deposits new layers of shell over its whole surface, so that the larval shell valves become separated from the mantle by the new layers (plate ix, fig. 3, *S*), which crop out beyond their margins and acquire the characteristic prismatic and nacreous structure. The summits of the outer faces of the umbones thus correspond with the places of the larval valves, which soon cease to be discernible. After a time the body becomes convex on the left side and flat on the right; the successively added new layers of shell mold themselves upon it, and the animal acquires the asymmetry characteristic of the adult.<sup>a</sup>

The horny convex shell of the fry (plate ix, fig. 3, *L*) may be seen, for a considerable time after attachment, at the umbo or beak of the developing shell of the spat (plate ix, fig. 3, *S*). The under or attached valve of the latter at first conforms closely to the surface to which it has become attached, being usually flat, but afterwards, as a rule, becoming deep and strongly concave, through an upgrowing along the edges.

#### FIXATION, SET, OR SPATTING.

At the time of fixation the fry will, under proper conditions, attach itself by its left valve to any hard or firm body with which it may come in contact.

The first essential is that the surface should be clean and that it should remain so a sufficient length of time to enable the young oyster to establish itself firmly. So long as this condition obtains, the nature of the material seems to matter but little. In most bodies of water the spat fixes itself at all levels from the surface to the bottom, but in certain parts of the coast its place of attachment is confined to the zone between high and low water, the mid-tide mark being the place of maximum fixation. It has been suggested that this was due to the density of the water preventing the sinking of the fry. There are a number of objections to this theory, but no better one has been offered, and it may receive provisional acceptance.

#### GROWTH.

At the time of its attachment the oyster fry measures about one-eightieth or one-ninetieth of an inch in diameter. The valves of the shell are strongly convex and symmetrical, and are composed of a horny material quite different from the finished shell of the adult.

The mantle, a thin flap of tissue which envelops the body of the oyster on each side, projects freely from between the lips of the valves and is the organ which secretes the shell. Upon its outer surface suc-

<sup>a</sup>Huxley, Thomas H.: Oysters and the Oyster Question. The English Illustrated Magazine, London, Oct., 1883, and Nov., 1883, vol. 1, pp. 47-55 and 112-121.



cessive layers of horny material are laid down, these becoming impregnated with calcareous matter arranged in a prismatic manner, and thus forming the stony shell which characterizes the adult.

The mantle increases *pari passu* with the growth of the soft parts in general, and as it is always capable of protrusion a little beyond the lips of the valves, it follows that each successive layer of shell is slightly larger than that which preceded it, and the shell increases in length and breadth as well as in thickness. From the nature of its growth, therefore, the youngest or newest part of the shell is on the inner face and at the edges, the latter always being sharp and thin in a growing oyster. The shell of the young oyster is always thin and delicate, and is generally more rounded than in the adult. The lower valve at first adheres closely to the body to which it is attached, but later its edge grows free and the valve, as a whole, becomes deeper and more capacious than its fellow. The small larval or fry shell remains visible at the beak of the spat shell for a considerable time, but becomes eroded away before the oyster reaches the adult condition.

The soft parts of the oyster assume their adult form in general soon after attachment, although the genital glands do not become functional until a much later period.

The rate of growth varies with locality and conditions. It is more rapid when food is abundant and at seasons when the oyster is feeding most vigorously, these conditions being filled most thoroughly in summer and fall, when the warm water increases the vital activities of both oyster and food.

In South Carolina oysters not more than six or seven months old were found to have reached a length of  $2\frac{1}{2}$  inches, and in the warm sounds of North Carolina they reach a length of  $1\frac{1}{2}$  inches in from two to three months. In the coves and creeks of Chesapeake Bay they attain about the same size by the end of the first season's active growth, and by the time they are 2 years old they measure from  $2\frac{1}{2}$  to  $3\frac{1}{2}$  inches long and from 2 to 3 inches wide. On the south side of Long Island the growth of the planted oysters is much more rapid than in Connecticut, it being stated that "two-year plants" set out in spring are ready for use in the following fall, while upon the Connecticut shore it would require two or three years to make the same growth. On the south side of Long Island oysters  $1\frac{1}{2}$  inches long in May have increased to 3 inches by November of the same year.

The amount of lime in the water is a factor in determining the character of the shell, and oysters growing in waters deficient in that respect have thinner shells than those which are well supplied, and are therefore more susceptible to the attacks of the drill.

The shape of the oyster to a certain extent determines its value in the market. Single oysters of regular shape with deep shells and plump bodies will bring a better price than those which are irregular

and clustered. The shape depends largely upon the degree of crowding to which the oyster has been subject. When numerous spat become attached to a single piece of cultch, such as an oyster shell, there is often insufficient room for the development of all. Many will be crowded out and suffocated, while the survivors will be distorted through the necessity of conforming to the irregular spaces between the valves of their fellows. Sometimes the pressure exerted between the rapidly growing shells is sufficient to break up the more fragile forms of cultch, and the separated oysters then usually improve somewhat in shape.

The crowding of oysters reaches its climax upon the "raccoon" oyster beds. Raccoon oysters are usually found in localities where the bottom is soft and the only firm place which offers itself for the attachment of the spat is upon the shells of its ancestors. Temperature and other conditions are favorable, growth is rapid, the young oysters are crowded into the most irregular shapes, the shells are long, thin, and sharp edged, and eventually the mass of young is so dense that it crowds out and smothers the preceding generations which produced it and offered means for its attachment. Oysters crowded in this excessive manner are poor flavored as well as ill shaped, but both defects are corrected if they be broken apart, as may be readily done, and planted elsewhere.



## OBSERVATIONS AND EXPERIMENTS ON THE GROWTH OF OYSTERS.

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By O. C. GLASER.

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### INTRODUCTION.

One can hardly fail to be impressed with the great diversity in the shape of oysters on the natural beds. Normal disk-shaped and oval individuals lie side by side with those of irregular and even grotesque form, while here and there in vertical clusters are narrow shells of extreme length. These narrow and elongated shells, which in some places predominate to the almost entire exclusion of all other shapes, are important agents in the formation of reefs, marshes, and islands.

The elongated condition of these oysters has been attributed to various causes. According to one view, the complete exposure to the air at every low tide accounts for it, but this explanation is entirely inadequate. Not only is it difficult to understand how such exposure could bring about the great increase in length which these oysters have experienced without corresponding growth in width, but it completely fails to account for the fact that equally elongated individuals are found on beds that are always below watermark and can not receive any periodic exposure to the air.

According to another view, this shape of the oysters is due to the fact that they are half buried in mud, because, in order to escape suffocation, they elongate into the clearer strata of water above them. This explanation is apparently more credible than the first, but it has still greater difficulties to overcome. If the presence of mud were the factor determining the elongation of oysters it would be difficult to find any that are not elongated, and it would be useless to look for well-shaped oysters in many places from which we gather large and choice specimens for the market. It would also be useless to look for elongated forms on the reefs where they are now most abundant, because these reefs are almost entirely composed of shells and calcareous sand. That there is nothing in the general environment which effects the elongation of oysters is shown further by the fact that perfectly normal individuals grow on the elongated ones.

A third view attributes the elongated condition to crowding. Ryder, in his Contribution to the Life History of the Oyster, says that the natural tendency of oysters to grow upward accounts for the fact that they become crowded, and crowding makes them narrow and elongated. "In all the natural banks which I have had the pleasure of examining in the Chesapeake, the individual oysters assume an approximately vertical position. The assumption of this position seems perfectly natural. With the large end downward and the free edges of the valves directed upward the animals are in an excellent position to feed, while the outside vertical surfaces of the valves are well adapted to afford places of attachment for the spat. The habit of growing in the erect position, where the banks are prolific and undisturbed, causes the individuals to be very much crowded together, so that they do not have a chance to expand and grow into their normal shape. From this cause—overcrowding—the shells of the individual oysters become very narrow and greatly elongated. The peculiar forms which result are known to oystermen as 'raccoon oysters' or 'cat's tongues.'" Verrill, in his Vineyard Sound report, points out that old specimens in crowded beds often grow to be more than a foot long and, perhaps, only 2 inches wide. Professor Brooks, in his well-known book on the oyster, also thinks that the elongated forms are due to crowding: "The oysters are crowded together so closely that they can not lie flat, but grow vertically upward side by side. They are long and narrow, are fastened together in clusters, and are known as 'coon oysters.'" Dr. Caswell Grave, in his article on the oyster reefs of North Carolina (1901), believes that the oysters composing the clusters on the reefs are long and narrow on account of their crowded condition, and Dr. H. F. Moore, of the United States Fish Commission, in a personal communication, commits himself to the view "that the elongation of the oyster, tending to the raccoon type, is either due to crowding on the beds or to the attempt of the oyster to keep the lips of its shell above the surface of the soft bottom."

These opinions, with the exception of that of Moore, who thinks that the presence of mud may also be one of the reasons for the elongation, agree as to the cause of the shape of the oysters. Ryder thinks that the crowding is due to the natural tendency of oysters to grow upward. I have not been able to observe this natural tendency, and I believe with Professor Brooks that the crowding brings about the upward growth, and not the upward growth the crowding.

#### OBSERVATIONS.

Young oysters are frequently found covering shells, rocks, and other suitable material so completely that nothing can be seen of the objects to which they are attached. In such collections it is easy to see that

the proximity of the oysters to one another causes the thin growing margins of their shells to fuse and become folded upward. As they grow without any corresponding increase in the surface on which they have settled, those portions of the shells which have been made, after all the available surface has been used, become more and more raised, until finally the oysters are placed at a sharp angle to their original position. If growth continues they will finally be perpendicular to the surface of attachment.

Very frequently new spat settles on the shells which have been elevated, and if this new layer is sufficiently dense the shells again become crowded, misshaped, and elevated. If there were no irregularities in the shells to which they are attached they would ultimately stand at right angles to them. The first layer, however, presents so many openings and corners into which shells of the second layer may squeeze that these, instead of growing out at a sharp angle, usually are densely packed into the available crevices. In this way clusters are formed in which one may often count from five to seven generations. The oysters in these collections are nearly all misshaped or unduly elongated, and all such are oppressed on one or more sides by neighbors. Often the direction of growth is suddenly changed by a sharp angle and the edges of the shells follow even the minute indentations and irregularities of their neighbors. It seems clear from such clusters that the elongated and irregular shapes of the oysters are due to the fact that there is not room enough for them to expand and grow to the width which they might have attained had they been isolated or comparatively free.

One of the first facts to be noticed during a study of localities where elongated oysters grow is that normal adults occur frequently in the little bays and indentations of marshes, but are rare on the points, which are tipped with regions composed almost entirely of the elongated forms growing actively under an environment similar to that of the reef oysters. The oysters that grow in the marsh bays and inlets are surrounded by great quantities of mud, which is in part produced by decaying vegetable and other organic matter derived from the marsh itself, but probably is collected chiefly by the mass of green vegetation which acts as a sieve through which the water passes at high tide, parting with much of the matter that it holds in suspension. The mud thus collected accumulates, especially in the little bays and inlets, and after a heavy rain may rise several inches and smother a good many oysters which were on the surface of the old shore line. Sometimes the accumulation is very sudden and great. In making these observations on one occasion it was necessary to revisit, after some days, a certain little bay, and there I found a perfectly smooth and even muddy shore line, knee deep under which were the oysters I had come to examine.

From this it seems probable that the presence of mud, while it sacrifices many oysters, is good for those which survive, because they are freed from the crowding of neighbors. I suspect that the advantage of dragging a dredge over young beds not yet ready to yield a harvest, lies not only in the fact that in this way the clusters are forcibly separated, but that many young oysters, which would have grown to maturity and then crowded one another, are turned under and killed by the mud, giving their more fortunate neighbors a better opportunity for normal and regular growth.

The excessive crowding to which the oysters growing in clusters are subject has been held by Professors Brooks and Verrill to account for the fact that such collections, often numbering as many as 100, are frequently composed entirely of empty shells. The work of Doctor Grave on the conditions under which oysters feed lends strong support to the opinion that crowding may bring about the death of entire clusters, because it is almost certain that the individuals composing them are poorly fed, and therefore probably not so resistant as oysters growing alone or in less densely crowded communities. Doctor Grave has shown that under normal and favorable conditions a Newport River oyster takes one hour to strain 333 c. c. of water, and that it can obtain sufficient nutriment in from two to six hours. The thickest clusters of marsh and reef oysters are found where they are covered only during the last hour of flood tide, during slack water, and during the first hour of ebb tide, and in this brief period they must get their food. Thus the maximum time which many of these oysters have for feeding is little more than the minimum time during which their more fortunately situated relatives can procure all they need. The supply of food, shortened in this way by a disadvantageous position, is in all probability still further diminished as a direct result of the crowding. The density with which the elongated oysters are packed makes it almost certain that the water containing their food passes through more than one set of gills, and the amount that each individual can extract will depend on the number of times that the water has already been strained. Only the first oyster securing a given quantity of water has the opportunity of extracting from it all the diatoms that it contains.

While there seem to be good reasons for believing that the ill-nutrition and the crowding of oysters, caused by their location, may account for the fact that so many of them die, there is another possibility which must be taken into consideration in explaining the large numbers of clusters of empty shells. It is no rare occurrence for many of the animals inhabiting the sand flats to be killed at low tide by the great heat of the midsummer sun. There can be little doubt that the oysters also suffer during these periods of too high temperature, and it is very

probable that many of them, whether underfed or not, succumb. In the winter, also, exposure to too low a temperature may freeze them to death. These unfavorable temperatures surely occur with sufficient frequency to account in part for the great quantities of empty shells.

#### EXPERIMENTS.

I. *To ascertain whether normal oysters can be converted into elongated ones by pressure.*

Thirty round, well-shaped young oysters were removed from cultch taken from the experimental bed in Newport River. These oysters were fastened by means of Portland cement to slabs of slate and the cement was so piled up around them that each oyster was subject to pressure on two of its edges, the margin opposite the hinge being free. After the cement had hardened, the slabs were put in the water near the laboratory and left undisturbed for one month. At the end of this time they were removed and the oysters examined.

None had died, indicating that the abnormal conditions under which they had been placed were not unfavorable to life. None had grown in width, but all were longer than at the beginning. Some had the scolloped anterior edges characteristic of elongated oysters, and due probably to the fact that the laterally oppressed mantles, instead of spreading out flat and evenly, are thrown into folds. These results indicate that mechanical pressure may be an important factor in determining the shape of the shell.

II. *To ascertain whether elongated oysters liberated from an oppressive environment will change in shape.*

Thirty-five elongated and narrow young oysters were removed from their crowded condition, cleaned, and carefully measured. Their length was taken from the tip of the umbo of the upper valve to the middle of the anterior edge, and their width at a point on the same valve halfway between the two extremities of the first measurement. They were then placed in a cage made of galvanized iron wire, and this was suspended horizontally in the water under the laboratory wharf, where an especially strong tidal current prevails. After thirty, and again after forty-eight, days the above measurements were taken in the same way and compared with the initial figures. The results are given in the table following.



TABLE I.

August 2, 1902, initial measurement.			September 2, 1902, after thirty days.			September 18, 1902, after forty-eight days.		
Length.	Width.	Ratio of width to length.	Length.	Width.	Ratio of width to length.	Length.	Width.	Ratio of width to length.
Cm.	Cm.	Per cent.	Cm.	Cm.	Per cent.	Cm.	Cm.	Per cent.
4.2	2.1	50	2.9	2.1	72	4.9	3.7	76
6.6	3.0	45	2.7	2.1	78	5.7	2.6	46
3.7	1.9	51	4.6	3.1	67	4.2	2.1	50
5.0	2.1	42	5.8	3.0	52	4.0	2.3	58
4.0	1.5	38	2.4	2.2	92	3.7	2.6	70
4.0	2.3	58	3.3	2.0	61	6.0	3.0	50
3.5	1.9	54	3.6	2.5	69	5.4	3.3	62
5.9	2.6	44	4.0	2.2	55	3.8	2.0	53
3.4	1.9	56	4.1	2.4	59	4.9	2.9	57
3.6	2.5	69	4.1	2.1	51	3.2	2.8	88
3.8	1.9	50	3.6	2.0	56	5.0	3.3	66
4.2	1.8	48	3.0	2.0	67	4.1	2.5	61
3.6	1.9	53	5.1	2.5	49	5.2	2.8	54
2.2	1.2	55	4.2	2.5	60	7.1	3.6	51
3.0	1.7	57	5.0	3.0	60	3.4	2.9	85
2.5	1.1	44	3.9	2.9	74	2.9	2.9	100
2.6	1.9	73	3.7	2.4	65	4.2	3.1	74
3.2	1.2	38	3.8	3.0	79	4.6	2.8	61
4.0	2.1	53	3.5	2.3	65	4.5	3.0	67
3.8	1.8	55	3.1	1.9	61	4.5	3.0	67
3.2	1.8	56	3.5	1.9	54	4.0	3.0	75
4.2	2.2	52	4.3	2.8	65	3.4	2.4	71
3.0	1.4	47	3.8	2.3	61	4.3	3.5	81
3.1	1.4	45	5.0	2.9	58	4.2	2.4	57
2.0	.9	45	4.0	2.8	70	5.6	4.0	71
2.7	1.1	40	4.8	3.3	64	6.4	3.1	48
1.7	.9	53	4.1	3.1	76	5.4	4.0	74
2.8	1.9	68	4.6	2.3	50	4.2	3.3	79
2.4	1.5	63	3.6	2.2	61	3.6	2.2	61
2.5	1.4	56	6.7	3.1	46	4.3	2.9	67
2.6	1.8	69	3.6	2.3	64	4.0	2.7	68
2.9	1.5	52	6.2	3.1	50	4.1	2.7	66
3.8	2.1	55	3.0	2.0	67	4.2	2.5	60
2.3	1.2	52	(a)	(a)		(a)	(a)	
1.6	1.3	81	(a)	(a)		(a)	(a)	
Average ratio, 58.			Average ratio, 62.			Average ratio, 66.		

(a) Dead.

NOTE.—In taking the measurements and in calculating the percentage ratios of width to length decimals under 0.05 were neglected and 0.05 and over were counted as .1.

From this table it is evident that at the beginning of the experiment, August 2, 1902, the width of this lot of oysters was only 53 per cent of the length, whereas on September 2 it was 62 per cent, an increase of 9 per cent; on September 18 it was 66 per cent, an increase over the original ratio of 13 per cent. This marked change, easily noticeable without measurements, was very surprising because it took place in forty-eight days after the liberation of the oysters from their original oppressive environment.

To compare these oysters with the normally shaped ones from the experimental bed in Newport River, thirty young oysters from this locality were measured in the same way:

TABLE II.

Length.	Width.	Ratio of width to length.	Length.	Width.	Ratio of width to length.
<i>Cm.</i>	<i>Cm.</i>	<i>Per cent.</i>	<i>Cm.</i>	<i>Cm.</i>	<i>Per cent.</i>
3.1	2.9	94	3.3	3.3	100
5.0	3.5	70	4.6	3.6	78
2.8	1.8	78	4.8	3.5	73
2.9	3.0	103	5.4	3.5	67
4.8	3.0	63	3.6	2.8	78
4.9	3.7	76	2.8	2.6	93
5.4	3.3	61	5.0	2.9	58
5.0	4.2	84	3.5	2.5	71
4.1	3.0	76	5.6	3.9	70
5.0	3.6	72	3.7	3.3	89
5.7	4.3	75	4.8	3.7	77
4.2	3.6	86	4.0	3.6	90
5.7	4.0	70	3.5	2.8	80
5.5	3.8	69	2.5	3.0	120
4.0	3.1	78	2.4	2.0	83

Average ratio of width to length 79 per cent.

These measurements show that in some cases a young oyster is actually wider than it is long, and the occurrence of such makes the ratio of width to length very high. For the present lot it was 79 per cent.

The oysters used in Experiment II were, according to their size, of about the same age as the normal spat, and the two groups can therefore be compared. At the beginning the width of the experiment oysters was only 53 per cent of their length, or 26 per cent less than the similar relation in the normal spat. On September 2 it was 62 per cent, or 17 per cent below normal, and on September 18 it was 66 per cent, or 13 per cent below normal, showing a steady approximation to the condition found in oysters which have never been subject to crowding.

This comparison between the normal spat and the young elongated forms suggested a similar one between adults of normal shape and elongated oysters of about the same size and approximately the same age. The length and width of these were measured by the method employed with the younger oysters.

TABLE III.

Normal adults.			Elongated oysters.		
Length.	Width.	Ratio of width to length.	Length.	Width.	Ratio of width to length.
<i>Cm.</i>	<i>Cm.</i>	<i>Per cent.</i>	<i>Cm.</i>	<i>Cm.</i>	<i>Per cent.</i>
10.7	6.2	57	10.0	3.2	32
8.8	4.8	55	7.8	4.0	50
8.7	4.3	49	9.4	3.9	41
8.5	4.6	54	8.4	3.3	39
9.0	6.0	67	7.4	3.0	41
8.9	5.4	61	7.8	3.2	41
9.9	5.3	54	8.6	3.5	41
9.4	4.6	49	8.0	3.8	48
7.3	4.5	62	7.6	2.8	37
8.9	5.7	64	6.5	2.7	42
7.5	4.1	55	7.6	3.7	49
8.2	4.6	56	6.0	2.6	43
8.8	4.0	45	8.9	3.5	39
8.3	5.2	63	6.8	3.5	51
6.5	4.4	68	7.3	3.7	51
6.6	3.4	52	7.7	2.9	34
7.7	4.4	57	8.0	2.9	36
9.0	4.8	53	8.7	3.9	45
6.7	4.5	67	6.3	2.7	43
9.5	3.7	39	6.3	2.5	40
3.2	4.0	43	6.4	3.0	47
7.2	4.7	65	7.6	2.6	34
8.4	4.5	54	6.5	2.7	42
8.7	4.9	56	7.7	2.1	27
7.7	4.3	56	8.1	2.3	28
8.8	4.8	55	7.0	3.4	49
10.0	5.2	52	6.5	2.9	44
6.2	4.0	64	7.6	3.1	41
8.1	4.8	59	8.3	3.8	46
8.0	4.3	54	6.3	2.4	38
Average ratio, 56.			Average ratio, 41.		

These measurements illustrate very strikingly that oysters normally grow longer than they do wide, so that a large, well-shaped adult oyster may, in the relation between its width and its length, give a figure far below the one expressing the same relation in younger stages.

At first glance it might possibly be thought that the adult "normal" oysters were not normal at all, because their width was only 56 per cent of their length, being 13 per cent lower than the ratio between the width and length of the young spat referred to in Table II. This, however, is by no means the case, because the relation between width and length varies with the age. An old "normal" oyster is not a "good" oyster; thus the interesting fact is brought to light that a condition which normally occurs only in oysters of extreme old age may be induced in young ones by crowding. As far as the relations between width and length are concerned, therefore, young elongated oysters are in a state of premature old age. Verrill long ago pointed out that great increase in length without corresponding growth in width is the natural order of things. "Nearly all the oyster shells composing the ancient Indian shell heaps along our coast are of this much elongated kind. Nowadays the oysters seldom have a chance to grow to such a good old age as to take on this form, though such are occasionally met with in deeper water." Such mounds as Profes-

sor Verrill mentions occur at Marshallsburg, N. C., and there this kind of oyster shell is extremely abundant. The same type of shell, commonly known as the "razor blade," is also found, sometimes with the animal still alive, on the shores of the Newport River marshes.

III.—*To ascertain whether the recuperative power of elongated oysters varies with their age.*

Experiment II clearly demonstrates the fact that oysters grown under oppressive conditions are capable of changing in shape and assuming ultimately a form normal for their age. It is desirable, however, to know how late in life an oyster is still able to take advantage of new opportunities, and for this purpose the following experiment was made:

Ninety oysters were liberated from the most oppressive surroundings and were divided roughly, according to length, into three lots—(A) containing all sizes up to and slightly over an inch, (B) sizes between 1 and 2 inches, and (C) all measuring 3 inches or more in length. These three lots were measured, as in experiment II, and then placed in separate galvanized iron wire cages which were suspended horizontally under the wharf, as in the former experiment. They were placed in the water on September 5, 1902, and removed on November 5. The measurements were as follows:

TABLE IV.  
SEPTEMBER 5, 1902.

A			B			C		
Length.	Width.	Ratio of width to length.	Length.	Width.	Ratio of width to length.	Length.	Width.	Ratio of width to length.
<i>Cm.</i>	<i>Cm.</i>	<i>Per cent.</i>	<i>Cm.</i>	<i>Cm.</i>	<i>Per cent.</i>	<i>Cm.</i>	<i>Cm.</i>	<i>Per cent.</i>
4.7	2.1	45	5.4	3.0	56	10.0	3.2	32
3.6	2.0	56	4.6	1.9	41	7.8	4.0	50
4.6	1.9	41	5.7	1.6	28	9.4	3.9	41
2.6	1.3	50	5.6	2.5	45	8.4	3.3	39
4.8	2.2	46	5.5	1.9	35	7.4	3.0	41
2.3	1.5	65	5.4	2.5	46	7.8	3.2	41
3.7	1.9	51	5.0	2.0	40	8.6	3.5	41
3.0	1.4	47	5.5	2.1	38	8.0	3.8	48
3.9	2.2	56	5.8	2.7	48	7.6	2.8	37
2.7	1.2	44	5.4	3.1	57	6.5	2.7	42
3.9	2.2	56	4.7	2.9	62	7.6	3.7	49
2.1	1.1	53	7.0	2.5	36	6.0	2.6	43
3.3	1.3	39	5.3	1.7	32	8.9	3.5	39
4.1	1.8	44	4.6	2.1	46	6.8	3.5	51
2.9	1.2	41	4.8	2.0	42	7.3	3.7	51
3.5	1.5	43	5.5	2.4	44	7.7	2.6	34
4.3	2.2	51	4.8	2.2	46	8.0	2.9	36
3.3	2.1	64	5.3	2.7	51	8.7	3.9	45
3.8	1.9	50	5.4	2.3	43	6.3	2.7	43
3.0	1.8	60	5.2	2.4	46	6.3	2.5	40
3.1	1.4	45	5.0	2.3	46	6.4	3.0	47
4.8	2.0	42	4.6	2.7	59	7.6	2.6	34
2.2	1.0	45	5.1	1.8	35	6.5	2.7	42
3.8	1.9	50	4.8	2.0	42	7.7	2.1	27
2.1	1.4	67	6.2	2.6	42	8.1	2.3	28
3.7	1.6	43	5.2	1.7	33	7.0	3.4	49
3.7	1.7	46	5.6	2.1	38	6.5	2.9	44
4.3	2.1	49	5.4	2.5	46	7.6	3.1	41
3.0	1.3	43	5.5	2.6	47	8.3	3.8	46
3.0	1.6	53	5.0	2.2	44	6.3	2.4	38
Average ratio, 50.			Average ratio, 44.			Average ratio, 41.		

NOVEMBER 5, 1902.

A			B			C		
Length.	Width.	Ratio of width to length.	Length.	Width.	Ratio of width to length.	Length.	Width.	Ratio of width to length.
<i>Cm.</i>	<i>Cm.</i>	<i>Per cent.</i>	<i>Cm.</i>	<i>Cm.</i>	<i>Per cent.</i>	<i>Cm.</i>	<i>Cm.</i>	<i>Per cent.</i>
4.2	2.8	67	5.8	3.3	57	6.9	3.2	46
4.6	3.5	76	6.6	3.9	59	9.0	3.8	42
4.0	2.8	70	4.4	2.7	61	6.7	3.7	55
4.5	2.9	64	7.1	3.6	51	7.4	3.8	51
3.6	2.8	78	6.2	3.0	48	7.6	3.6	47
4.5	2.9	67	5.9	3.5	59	8.6	4.3	50
4.3	2.5	58	6.0	3.4	57	8.6	4.3	50
3.1	2.3	74	5.8	2.9	50	8.3	3.8	46
4.8	3.1	65	5.5	2.5	45	8.2	4.0	49
3.1	2.3	74	6.2	3.1	50	6.6	3.3	50
5.5	2.9	53	6.0	3.3	55	7.3	3.6	49
4.2	2.7	64	5.5	2.7	49	7.6	3.2	42
5.7	3.3	58	6.3	3.4	54	7.3	3.9	53
4.3	3.0	70	5.8	3.8	66	7.9	3.4	43
4.1	2.5	61	5.8	2.7	47	9.5	4.2	44
3.0	2.5	83	5.4	2.9	54	7.9	3.3	42
3.1	2.5	81	7.1	3.3	46	8.1	3.1	38
5.6	3.3	59	5.9	3.1	53	7.7	4.0	52
3.3	2.2	67	5.8	2.9	50	7.9	4.3	54
5.0	3.3	66	5.1	3.4	67	8.3	2.9	35
4.0	2.7	68	6.3	3.3	52	6.6	2.9	44
5.8	3.7	64	6.1	3.7	61	7.4	4.0	54
4.5	3.1	69	5.7	3.0	53	6.3	3.2	51
4.8	2.7	55	(a)	(a)		6.4	3.4	53
3.7	2.4	65	(a)	(a)		(a)	(a)	
4.6	3.4	74	(a)	(a)		(a)	(a)	
3.9	2.4	62	(a)	(a)		(a)	(a)	
4.6	2.6	57	(a)	(a)		(a)	(a)	
(a)	(a)		(a)	(a)		(a)	(a)	
(a)	(a)		(a)	(a)		(a)	(a)	
Average ratio, 68.			Average ratio, 54.			Average ratio, 47.		

(a) Dead.

The oysters in lot A were of the same age as those used in experiment II, and a comparison of the measurements of the two groups fully corroborates the earlier results. The final measurements of lot A were made two months after the oysters had been liberated, and show more strikingly than the former experiment that elongated oysters are capable of approaching a normal shape with surprising rapidity. Two photographs were taken of this particular lot (plate x), and these illustrate as forcibly as the figures the great change that took place.

A comparison of the initial and final measurements of lots A, B, and C also shows that the recuperative power varies with age. On September 5 the ratio of width to length was 50 per cent in lot A, 44 per cent in lot B, and 41 per cent in lot C, whereas on November 5 the same lots presented respectively a percentage of width to length of 68, 54, and 47 per cent. Thus in all an improvement in the relation between width and length took place, lot A increasing 18 per cent, lot B 10 per cent, and lot C 6 per cent. This gradation is just what would be expected from the fact that oysters approaching old age normally grow longer than they do wide.

Of the oysters used in this experiment lots A and C, on account of



LOT A (EXPERIMENT III) AT BEGINNING OF EXPERIMENT, SEPTEMBER 5, 1902. (THREE-TENTHS NATURAL SIZE.)



LOT A (EXPERIMENT III) AT END OF EXPERIMENT, NOVEMBER 5, 1902. (THREE-TENTHS NATURAL SIZE.)



their original size, can be compared with the spat and normal oysters of Tables II and III. Such a comparison of the percentage ratios in the three tables shows that at the beginning lot A was 29 per cent below normal and lot C 15 per cent below normal, whereas after 60 days of improved surroundings lot A was only 11 per cent below normal and lot C 9 per cent below normal, demonstrating that the recuperative power of lot A was exactly three times that of lot C.

Without attaching too much weight to the results, it is interesting to note in what time these two lots A and C would have reached the normal states for their respective ages, if the rates of growth had continued what they were during the sixty days of the experiment. In lot A, in sixty days, the relation between the width and the length changed from 50 to 68 per cent, an average daily change of three-tenths per cent. According to Table II the normal condition is 79 per cent, from which it follows that at the rate of three-tenths per cent change per day, it would have taken this lot of oysters ninety-seven days (probably less, because at the age then attained the normal would be less than 79 per cent) to make up the discrepancy between 50 and 79 per cent. In lot C, on the other hand, the relation between the width and the length changed in sixty days from 41 to 47 per cent, a daily change of one-tenth per cent. According to Table III, the normal for this age is 56 per cent, from which it follows that at the rate of change of one-tenth per cent per day, lot C would have taken one hundred and fifty days to attain a normal condition. The recuperative power of the younger oysters is so much greater than that of the older ones, that in spite of the fact that they are much further below normal, they are nevertheless capable of realizing this condition in much less time.

The young oysters, besides having the advantage over the older ones of possessing greater recuperative power, seem also to possess greater resistance to the ill effects almost certainly attendant on a sudden change of environment. Not enough cases have been noted, of course, to establish this fact with a great degree of certainty, but a glance at Table IV will show that the mortality in lots B and C respectively was 23 and 20 per cent while it was only 7 per cent in lot A.

#### CONCLUSIONS.

The elongated condition which many oysters exhibit before they have attained old age is due to crowding. A great increase in length without an apparently proportionate increase in width represents the normal growth of an oyster, and the so-called "razor blades," much narrower than many of the elongated marsh and reef oysters, exhibit this condition, not because they have grown under unfavorable conditions, but because they are old. The elongated oysters which have been considered in this paper are young, and their shape is abnormal.



Because they have the same forms and proportions of much older normal oysters they may be said to be in a state of premature old age.

The crowded condition of these prematurely old oysters makes it impossible for them to expand and grow to a width normal for their age. They have the power to expand, however, when removed from this crowded condition, and this expansion takes place so rapidly that for the periods during which they were under observation they grew more in width than in length. This is exactly what happens in very young oysters that have settled where they have abundant room. Under such favorable conditions the growth in width, for a period at least, is equal to the growth in length, and at times the former measurement may even exceed the latter. After this period in early youth the growth in width steadily decreases until the oyster reaches old age. Under unfavorable crowded conditions the growth in width is inhibited immediately after the period during which it is equal to or greater than the growth in length. If the hindrance is removed, a growth in width exceeding the growth in length nevertheless takes place. It seems as though the shell made up the loss which is the result of the crowding.

If we were to represent the normal growth in length and width by two curves, the width curve would, in the beginning, rise to the same or to a greater height than the length curve, but as the shell grew older the width curve would descend and the length curve rise until the original condition was reversed. In the elongated oysters, the width curve would have an early rise corresponding to the rise in the normal width curve, then a sudden fall, and, after isolation, another rise which would not be found in the normal curve. After this second rise the width curve would descend and correspond, in all probability, to the normal width curve for corresponding ages. The length curve of the elongated oysters would probably correspond stage for stage with the normal length curve, because the elongated oysters owe their condition, not to excessive length, but to excessive narrowness.

The recuperative power of oysters that have lived under oppressive conditions varies with their age. Young individuals recover much more rapidly than old ones, though these too improve to a marked degree. The latter, however, seem less able to adapt themselves to a sudden and violent change of environment, and the mortality among them is much greater than among younger ones.

These facts have a decided economic bearing. The experience of oystermen, in Northern waters especially, has shown that oysters can be transplanted with great profit. At present millions of young spat settle on the shells fringing the marshes and reefs, and there, under unfavorable conditions, grow into the elongated forms which have no market value. In this paper evidence is brought forward which shows that these oysters, when separated from the oppressive conditions

under which they have grown, are able to recover and assume normal shapes.

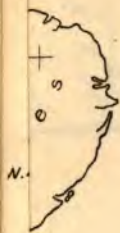
The advantages which this class of seed offers to planters are its cheapness and the fact that the oysters are older and larger than those ordinarily used for planting. The most promising size is between 1 and 2 inches in length. After separation the oysters should not be left where they became crowded, but should be transplanted to properly located natural or artificial beds. There they will have favorable conditions of food, and in addition will be free from the danger of again becoming crowded, as the number of spat that settles on shells in wisely chosen localities is very much less than that which settles and continues to exist on the shells of the marshes and reefs.

N.

• A

B

36°



0.1



B A N

36'



36'

36'

36'

36'

36'



36'

